ELECTRO-DIAGNOSIS *and* ELECTRO-THERAPEUTICS

A GUIDE FOR PRACTITIONERS AND STUDENTS

By DR. TOBY COHN

Nerve Specialist

BERLIN

Translated from the Second German Edition and Edited by

FRANCIS A. SCRATCHLEY, M.D.

NEW YORK

Chief of Clinic, Diseases of the Nervous System, and Instructor in Electro-Diagnosis and Electro-Therapeutics, University and Bellevue Hospital Medical College; Consulting Neurologist to the Home for Incurables, etc.

WITH EIGHT PLATES AND THIRTY-NINE ILLUSTRATIONS

FUNK & WAGNALLS COMPANY

NEW YORK AND LONDON

1904

[Printed in the United States of America]
Published, May, 1904

To

MY RESPECTED CHIEF,

PROFESSOR MENDEL,

AS A MARK OF GRATITUDE.

PROFESSOR MENDEL'S PREFACE TO THE FIRST EDITION

I TAKE great pleasure in recommending this guide to electro-diagnosis and electro-therapeutics.

For a number of years my colleague, Dr. Cohn, has supplemented my lectures by giving my hearers practical instruction in electro-diagnosis and electro-therapeutics. This book had its origin in that instruction.

I have had manifold opportunities to observe the work of Dr. Cohn, and have noted the interest and enthusiasm of the students in his courses, as well as the excellent practical results of the instruction.

Therefore, because this book has specially in view the interests of the beginner and of the practical student, and because it presents only the important facts in an easily intelligible form, I do not doubt that it answers a practical need, and will win and maintain a place for itself, notwithstanding the numerous and excellent works in this special line.

I cordially wish the respected author the best of success.

E. MENDEL.

AUTHOR'S PREFACE TO FIRST EDITION

To add another text-book to the already numerous list in existence—some more exhaustive, some more voluminous than this—is an act which demands justification.

I have written this short guide, not to introduce any new subject-matter, but because I myself wished to make an attempt, hitherto unsuccessful, to win the interest of the great mass of students and practising physicians, who are still almost thoroughly ignorant of the subject-matter treated in this book, by presenting the old subject in a form which may perhaps appeal to them.

In courses given to students and physicians at Professor Mendel's Polyclinic, the fact has certainly become evident to me that students of medicine and physicians have in general an aversion to all mathematical explanations and technical discussions with which text-books of electro-therapeutics usually begin.

This is, to quite an extent, the reason why those about to take up the study of therapeutics are discouraged at the very outset from approaching the matter more closely. And if this is the case with regard to the smaller books of our branch, some of which are really too brief upon the very important matters they discuss, or are

extremely bigoted upon the subject of therapeutics, then surely the beginner will not venture near the larger books, which present all the material in its most minute details —altho it is just such works as those of Erb, E. Remak, Rosenthal and Bernhardt, Lewandowski *et al.*, that are not only permanent contributions to neurological and medical literature, but also enduring monuments of German science and scholarship.

In this guide I have deemed it best, from experience gained in the delivery of my lectures, to begin at once, after a few introductory remarks, with the description of a single apparatus, a stationary apparatus for galvanic and faradic currents. In this way, with the help of a kind of object teaching, a practical demonstration of the principles, I am able to finish the unavoidable physical technical part as soon as possible.

After a physical introduction, bringing in only the most salient points, I enter upon methods of examination and pathology.

Now this demonstration of apparatus by means of drawings is not nearly so easy nor so effective as a course at the apparatus itself; but since it is my opinion that the subject-matter here treated can not possibly be learned from books alone, I assume that this guide-book is to be used either to finish up a course, and thus to supplement the same, or that it will enable a practising physician at the apparatus to understand what can be done with it. Even if this apparatus is not stationary, or is of any other construction than the one described, *mutatis mutandis* by a study of the last chapter treating

about apparatus, it will not be difficult for the practitioner to comprehend the matter.

In the presentation of the physiological and pathological conditions in the diagnostic part of the book, I have proceeded from the point of view that one must not confuse the beginner at the very start by mentioning innumerable possibilities and variations, however interesting these may be in themselves. I believe the aim of a guide-book for beginners is, rather, first to represent types which can be easily comprehended and retained; then, of course, when these types have been impressed upon the student's mind, to direct his attention constantly to the fact that these are only types, and as such allow of numerous variations and modifications; and, last, to have him notice all these, or at least those important for the practising physician. This is the plan followed in this book. No matter how schematic a good deal of it may appear, I have felt it my duty to present it just so schematically at first, altho in every case I have not refrained later, either in the text or in footnotes, to limit what was said, to correct it, and even in some cases partly to recall it.

The electro-therapeutic part is less in extent than the diagnostic. I think I have learned from experience that any one who commands a knowledge of electro-diagnosis can quickly and easily comprehend the electro-therapeutical technical terms, while without such previous knowledge he learns these terms with great difficulty or not at all. That in the comprehension of the working of the electro-therapeutic currents skepticism is necessary need

extremely bigoted upon the subject of therapeutics, then surely the beginner will not venture near the larger books, which present all the material in its most minute details —altho it is just such works as those of Erb, E. Remak, Rosenthal and Bernhardt, Lewandowski *et al.*, that are not only permanent contributions to neurological and medical literature, but also enduring monuments of German science and scholarship.

In this guide I have deemed it best, from experience gained in the delivery of my lectures, to begin at once, after a few introductory remarks, with the description of a single apparatus, a stationary apparatus for galvanic and faradic currents. In this way, with the help of a kind of object teaching, a practical demonstration of the principles, I am able to finish the unavoidable physical technical part as soon as possible.

After a physical introduction, bringing in only the most salient points, I enter upon methods of examination and pathology.

Now this demonstration of apparatus by means of drawings is not nearly so easy nor so effective as a course at the apparatus itself; but since it is my opinion that the subject-matter here treated can not possibly be learned from books alone, I assume that this guide-book is to be used either to finish up a course, and thus to supplement the same, or that it will enable a practising physician at the apparatus to understand what can be done with it. Even if this apparatus is not stationary, or is of any other construction than the one described, *mutatis mutandis* by a study of the last chapter treating

about apparatus, it will not be difficult for the practitioner to comprehend the matter.

In the presentation of the physiological and pathological conditions in the diagnostic part of the book, I have proceeded from the point of view that one must not confuse the beginner at the very start by mentioning innumerable possibilities and variations, however interesting these may be in themselves. I believe the aim of a guide-book for beginners is, rather, first to represent types which can be easily comprehended and retained; then, of course, when these types have been impressed upon the student's mind, to direct his attention constantly to the fact that these are only types, and as such allow of numerous variations and modifications; and, last, to have him notice all these, or at least those important for the practising physician. This is the plan followed in this book. No matter how schematic a good deal of it may appear, I have felt it my duty to present it just so schematically at first, altho in every case I have not refrained later, either in the text or in footnotes, to limit what was said, to correct it, and even in some cases partly to recall it.

The electro-therapeutic part is less in extent than the diagnostic. I think I have learned from experience that any one who commands a knowledge of electro-diagnosis can quickly and easily comprehend the electro-therapeutical technical terms, while without such previous knowledge he learns these terms with great difficulty or not at all. That in the comprehension of the working of the electro-therapeutic currents skepticism is necessary need

not be emphasized here. I can not, however, accept the theory of the "suggestionists," who claim that the curative powers of the current are entirely psychical.

Inasmuch as I consider it wrong to underestimate electro-therapeutics, just so would I warn against overestimating electro-diagnosis. The text repeatedly emphasizes this point, and yet here again I will lay stress upon the fact that electrical investigation forms but a very small fraction of all the methods of investigation; it is indispensable in many cases, but is never alone sufficient for diagnosis.

An appendix about Franklinization introduces the beginner as briefly as possible to the most important points of this subject worth knowing. I could not bring myself to include in this guide d'Arsonval's current of high frequency, since as yet it has not been introduced into Germany, and since what is known of it is too meager and needs critical examination.

I have also excluded galvano-cautery as well as the subject of electrical lighting and trans-illumination.

I am obliged to Mr. W. A. Hirschmann, who placed at my disposal the negatives of the drawings of the instruments, and to Mr. Arthur Sevin, who completed the rest of the drawings.

Special thanks are due to the publishing house, that in a worthy and obliging manner has endeavored to give the guide a handsome exterior.

TOBY COHN.

BERLIN, September, 1898.

AUTHOR'S PREFACE TO SECOND EDITION

In order to keep pace with the advances in science, and the many changes naturally occurring in my own opinions and experience during the course of three years, a complete revision of the entire book, and a partly working over of entire sections have been found necessary in this, the second edition of the guide to electro-diagnosis and electro-therapeutics.

Since in addition to this a number of figures had to be added, and the old figures somewhat altered, there existed the danger that the book would assume a form which would differ materially from the old one, in which, to my great pleasure, the book, in a relatively short time, attained a general circulation, and met with commendatory criticism.

By means of the greatest possible condensation of explanations, by relegating to remarks and footnotes opinions which are still a matter of discussion, and those which are practically unnecessary for the purpose of the book, and by the most conservative treatment in the text revision, I have endeavored to avoid this danger of unwelcome innovation, and to maintain the book in its old approved handy form.

Nevertheless in obedience to a general desire, I have somewhat increased the therapeutic part, and also added

a chapter on Teslaic currents, and an appendix concerning new methods in the application of forms of electricity.

I made these additions reluctantly, for good methods of application, much less new ones, are as rare as critical electro-therapeutists; and, in regard to the curative powers of Teslaization, notwithstanding the lively propaganda made for this form of treatment, my opinion, based upon the recent work of others in therapeutics, and also upon my own investigations, is not very far removed from skepticism. Disregarding all this, however, I have made the above-named additions, because in the absence of positive reasons, I did not feel justified in withholding these things from my readers, no matter how questionable they may appear to me.

The advice given me by one of my critics—to introduce more physics—I have not followed because I consider it entirely erroneous. On the contrary, I have found in every course of lectures which I have delivered that practical electro-physical discussions neither arouse great interest nor are they very well understood.

Also, in spite of advice to the contrary, I have held to the principle of demonstrating all diagnostic and therapeutic proceedings (in so far as they concern galvanic and faradic currents) with the same stationary apparatus, and to describe other constructions later in a special chapter. This division of materials is perhaps logically open to attack, but didactically it certainly answers the purpose.

In regard to this it is of course immaterial whether the

apparatus chosen for description was a stationary one made by the firm X, or a portable one by the firm Y. In the face of the innumerable constructions which exist, a portion of the readers would in any case have to fall back upon combinations and individual interpretations.

A complete orthography is included in the new edition, and misleading errors occurring in the text and print of the first edition have, as a matter of course, been eliminated.

I take this opportunity of most cordially thanking my colleagues, who by encouragement and advice have shown their interest in my work. I would also like to thank my dear and honored father, who has aided me untiringly in this revision, for his painstaking cooperation.

I also thank my publisher, Mr. Karger, for his constantly friendly attitude toward me.

TOBY COHN.

BERLIN, April, 1902.

EDITOR'S PREFACE

THE translation of Dr. Toby Cohn's Guide should prove of great service to physicians. It gives concisely all that is important in electro-diagnosis, and in electrotherapeutics all that is of positive value. It places electricity exactly where it belongs in a physician's armamentarium, as a curative agent. It will commend itself because of its excellent plates, its precise and very thorough explanation of the method of investigation and how to make an electrical diagnosis, and the careful instruction it gives for the proper use of electricity as a therapeutic agent. It presents so many good features in such an admirable manner that it should readily fill in this country the same place it has filled in Germany.

FRANCIS A. SCRATCHLEY.

NEW YORK, March, 1904.

PART I

ELECTRO-DIAGNOSIS

CHAPTER I

EXPLANATION OF THE APPARATUS

(*Physical Introduction*)

THE GALVANIC APPARATUS

The Cell

WHEN two metals—as, for example, a piece of zinc and a piece of carbon—are immersed in a liquid—say, a weak acid solution—then they acquire a particular form of potential energy (electrical energy) under a certain tension, which is different in the two metals. Such a combination is called a GALVANIC CELL.

Tension Series

The metals used in a galvanic cell have been arranged in a so-called "TENSION SERIES," in which relative difference of tension is indicated by position in the series: the nearer two metals are to each other in the series, the smaller is the difference in their tension; the farther they are apart, the greater is their difference. This series is as follows:

Zinc,
Lead,
Tin,
Iron,
Copper,
Silver,
Gold,
Platinum,
Carbon,
Manganese.

In a cell consisting of zinc and lead, or of carbon and manganese,

the difference in tension is extremely small; in a cell of zinc and manganese the greatest of all.

If we connect the free ends (poles) of the two metals immersed in the fluid with a conductor of electricity—as, for example, a copper wire—then the different tensions in the now-closed circuit—metal I., fluid, metal II., copper wire—will begin to neutralize each other; and since, through the constant contact of the metals with the fluid, a continual, constantly renewed collecting of electrical energy takes place within them, therefore the neutralization will be, not only a momentary, but a constant one. This self-replacement is called "a current of electricity" (constant current, galvanic current) (Fig. 1).

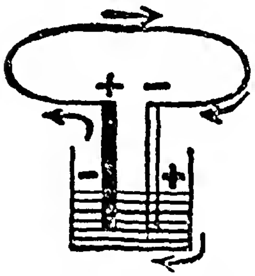


FIG. 1.—Diagram of Cell. The light line plate, zinc; the dark plate, carbon; the arrow indicates the current course.

The greater the difference in tension of the two metals of the cell—*i.e.*, the farther they are apart in the tension series—the greater will be the energy of the current. The ability of a cell to generate an electric current is called *the electromotor force of the cell* (E). The electromotor force of the cells, therefore, increases in proportion to the distance between the metals in the tension series. Thus a zinc-manganese cell or a zinc-carbon cell would have the ability to generate the greatest electromotor force possible.

We distinguish a current in the neutralization of the different tensions. This takes place in the liquid, passing from the metal higher up in the tension series to the

one lower down. For instance, in a zinc-carbon cell the neutralization, *i.e.*, the current, flows in the liquid from the zinc to the carbon; in a copper-wire—or any other body—connecting the free metals ("poles"), and which is known as the connecting-arc, naturally the direction will be an opposite one, that is, from the free carbon pole to the free zinc pole.

Of two metals in galvanic action, that which is higher up in the tension series is called positive, that which is lower down negative; and therefore we say, the current in a galvanic cell flows in the liquid from a positive to a negative metal. Accordingly, in a zinc-copper cell, zinc would be positive and copper negative; in a (hypothetical) copper-carbon cell the copper would be positive, the carbon negative, and the current in the liquid would flow from zinc to copper, and from copper to carbon.

Anode and Kathode

In the connecting-arc, in which, as before stated, the current flows in an opposite direction, we call the free end of the positive metal (as, for instance, the free zinc pole in the zinc-carbon cell) the negative pole or kathode, and the free end of the negative metal (the free carbon pole) the positive pole or anode.

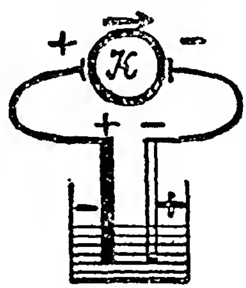


Fig. 2.—The Human Body in the Current Circuit.

Now imagine the connecting-arc to be severed at any one point, and that some other conductor of electricity, as, for example, a portion of the human body (*K*, in Fig. 2), be inserted at the point of interruption, then the current will flow in the same direction, through the

intervening body, and the point of entrance of the current will be called the anode (positive or + pole), and the point of exit the kathode (negative or − pole).

Those portions of the interrupted connecting-arc which are in immediate contact with the body, and which according to requirements may assume different forms, are called electrodes.

It is necessary, for therapeutic and diagnostic purposes, to be able to send through the human body cur-

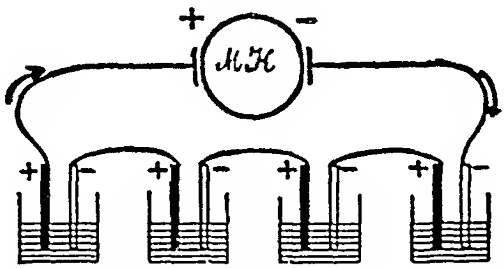


FIG. 3.—The Galvanic Battery. *MK*, Human body.

rents of different strengths, stronger and weaker (we also say greater or lesser currents). In order to allow of such gradation, several similarly formed cells are arranged in such a way that the negative pole of a preceding cell is always connected by means of a copper wire with the positive pole of a succeeding cell,* and this copper wire finally connects the free poles of the first and last cells with each other. This arrangement is called a GALVANIC BATTERY, and the electromotor force of the battery increases with the number of cells which compose it. The current in this battery and also in the

* These are also called by some "connection" or "consecutively placed" cells.

interposed human body has the same direction—from the first carbon to the last zinc pole. Therefore we use the terms anode and kathode of the battery. When it is possible to insert cell after cell, or several, or all simultaneously, in the current, then we can obtain a gradual increase or decrease in the strength of the current. An arrangement similar to this is attached to every apparatus made for medical use.

Stationary Apparatus

If we examine the stationary apparatus in the accompanying cut (Fig. 4), we see a case which contains a great number (thirty to fifty) zinc-carbon cells, of a particular construction (which will be described later on). These cells are connected with one another in the manner described above, and from the carbon pole of the first cell a metallic connection passes under the table of the apparatus to a screw (binding-post) of the stand. This screw is marked + and forms the anode of the battery. A similar connection passes from the zinc pole of the last cell to a screw or binding-post marked – which forms the kathode of the battery. From both binding-posts the connecting-arc is continued in the two conducting-cords (copper wires wound with silk and enveloped in rubber tubing for the purpose of insulation), to the electrodes provided with handles.*

If we apply the electrodes (moistened for reasons which will be stated later) to the human body, then the

*In order to distinguish, even at a distance, in which direction the current flows, the rubber tubes enclosing the conducting-cords are of different colors, red and black. Cords and electrodes are omitted in the cut.

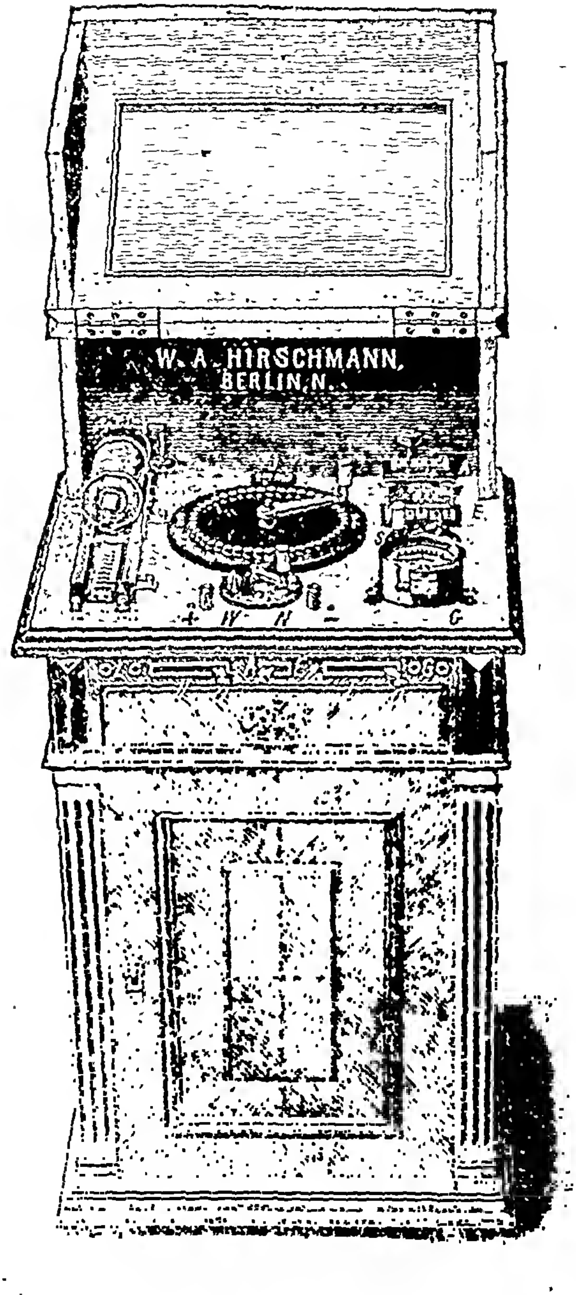


FIG. 4.—Stationary Apparatus.

current of the battery must flow through the body in a certain direction, namely, from the anode to the kathode.

Now on the table is a device which allows us to send through the body the entire current of the battery, or a greater or lesser current, according to the number of cells generating it. This device is the cell-collecting

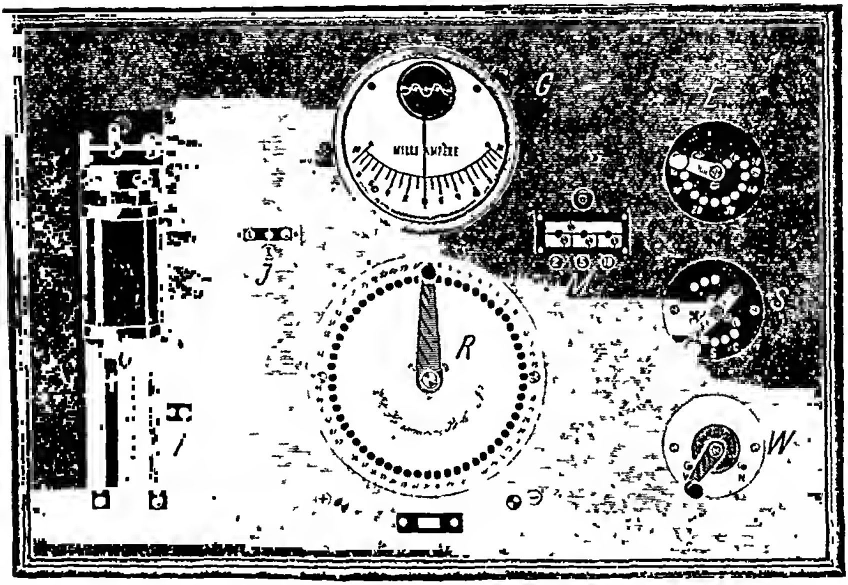


FIG. 5.—Table of Stationary Apparatus. *G*, Galvanometer; *R*, rheostat; *E*, cell collector; *J*, block with plug for the induction apparatus; *F*, faradic or induction apparatus; *W*, current reverser; *S*, current changer; *M*, multiplicator for the galvanometer.

switch, lettered *E* in Figs, 4 and 5. If the handle of this switch rests on *0*, then the circuit is open and no current passes through the connecting-arc. If the handle is placed at the contact-points marked 10, 20, 30, etc., then by means of a simple arrangement beneath the table a current generated by 10, 20, 30, etc., cells

will pass through, and thus a gradual strengthening or lessening of the current be made possible.

In many apparatus we can control the gradation more delicately, namely, from cell to cell—progressively and retrogressively—but this, as will soon be stated, is not at all necessary for practical purposes.

During the passage of the slowly strengthening current through the body, we experience a gradually increasing burning sensation of the skin, which in time becomes even painful.

At the same time we see, in the apparatus designated by *G*—the absolute galvanometer—a magnetic oscillating needle. The greater the number of cells included in the current, the greater will be the distance traversed by this needle. The needle moves along a scale, beginning at zero, in the middle of it, and indicates, by means of an empirical graduation according to a standard unit (milliampère), the strength of the current which is present in the human body.

The question then arises: Is it really necessary to have a measuring-apparatus like this? Can not the strength of the current present in the body be calculated from the number of included cells? Could we not say, a current generated by 10, 20, 30 cells is passing through the body?

That would be entirely wrong; the current applied to the body at the point for investigation—say the most sensitive spot of a muscle or a nerve—has not the same intensity at the moment of application as at the moment when it is generated in the cells.

On its passage from the cell to the muscle, the current loses in strength because of the resisting forces which oppose it. These are: first, the resisting forces in the cell itself (known resistance), and secondly, the resistance in the connecting-arc, which includes the human body (unknown resistance). The strength of the current in the body (intensity, I.), therefore, will increase with the number of included cells (electromotor force, E.); it will, in addition, be dependent upon the greatness of the resistance (R.), and the current will decrease in intensity with the increase in resistance, and *vice versa*. This is the exceedingly important FIRST OHMIAN LAW—the alpha and omega of electro-diagnosis. **First Ohmian Law**

$C. = \frac{E.}{R.}$, the strength of the current is equal to the electromotor force divided by the resistance.

Accordingly, when we wish to ascertain the strength of the current in the body, it does not suffice to know the number of included cells; we must also, by means of certain methods, determine the resistance exerted by the body, in order to calculate the value of the fraction $\frac{E.}{R.}$; and this is made possible by the absolute galvanometer. We may completely ignore the right side of the equation and answer the question concerning the intensity of the current, I., by reading it directly from the galvanometer in milliampères (ma.).

1 milliampère $= \frac{1}{1000}$ ampère.

1 ampère (standard unit of measure for the current intensity, I.) is $\frac{1 \text{ volt}}{1 \text{ ohm.}}$

1 volt (standard unit of measure for the electromotor force $= \frac{9}{10}$ of a freshly filled Daniell cell, and equals the amount of electricity which is set free by electrolysis in one second (at 0° and a pressure of 760 mm —0.1146 c.cm.H.).

1 ohm (standard unit of measure for resistance) is equivalent to the resistance of a column of mercury, 106 meters in length, and 1 sq. mm. cross-section, at 0° (C.).

Therefore it is wrong to say that a current of the strength of so and so many cells flows into the body; on the contrary, we may simply state that the strength of the current in the body equals so and so many ma.*

* In recent years Dubois, of Bern, in opposition to the above stated facts, and basing his conclusions on the results of numerous experiments, declared that the intensity, *i e*, the value $\frac{E.}{R.}$, does not always determine the power of the electric current; that, on the contrary, in nerve stimulation at the kathodal contact (see Chapter II.), the resultant contraction in the phase of the curve's increase is, on the whole, independent of the bodily resistance, and rather materially dependent on the electromotor force—the tension—of the current, and that the intensity of the current can be regulated by the resistance of the metals (see below under Rheostat). Hence, for example, we can obtain the same strength (in ma.) of the current by the unresisted action of ten cells, as by the partial action (weakened by the rheostat) of twenty cells, and yet occasionally a contraction will occur in the second case and not in the first.

If this is correct, then, in order to produce an effect in depth, we would have to regard the working of a galvanic-kathodal contact as similar to the spark of an induction-machine (see Chapter X.), whose scope and influence depend likewise simply upon the tension, and which overcomes the resistance of the skin and clothing with ease.

Since, however, the experiments of Dubois have been attacked on many sides (Hoorweg, Zanietowski, Mann, etc.), it is best not to draw any conclusions, and to hold to the above statements until a final decision concerning Dubois's theory has been made.

Many manufacturers, it is true, have already turned out station-

The Resistance

Since, according to Ohm's law, we must increase the electromotor force with the increase of the resistance, it is naturally of the highest importance that we know all the conditions of resistance.

While the resistance in the cells is of little account and rather constant in a good apparatus, and the resistance in the metallic connecting-arc, altho not insignificant, may be regulated at will (as will soon be shown), still the resistance which the human body offers the current is quite considerable in amount and subject to many variations. And among the tissues and organs of the body there is also one whose resistance is of great importance in the application of a current; that is, the skin. The resistance of the skin to the current is so great that, in comparison, the resistance of the other tissues of the body and of the cells need not be taken into consideration at all.

The Resistance of the Skin

The resistance of the skin varies in different places and at different times.*

Dry skin offers the greatest resistance to the galvanic

ary apparatus fitted not only with galvanometers (ampèremeters), but, in addition, with voltmeters, to calculate the intensity of the current as well as its tension (compare Chapter IX.). In fact, Zanietowski recommends that in examinations the volts should always be recorded, in addition to the milliampères.

*As may be seen from the above, it is rather immaterial, in calculating the strength of the current, whether the poles (electrodes) in contact with the body are near to each other or at some distance apart. Only the condition of the skin at the two points where the electrodes are applied is taken into account, since the resistance of all the other tissues along the path of the current is, comparatively speaking, easily overcome, and practically need not be taken into consideration.

current. Dry electrodes, placed on dry skin, offer an almost absolute resistance to even the most powerful currents. At the utmost, they simply act upon the surface, for they can not penetrate the skin. Therefore the electrodes (or the skin, or both) must be moistened if we wish the current to penetrate to any depth.

Those parts of the skin which are usually uncovered and possess a thick epidermis or covering of hair offer a greater resistance than other portions. The resistance is less in places where there are numerous sweat-gland ducts or hair-follicles, through which the current can slip in, so to speak.

Decrease of Resistance by Current

The fact that during the time in which a current is flowing through the body the action of the current itself decreases the resistance of the skin is of greatest importance. One may, for example, by inserting a portion of the body (the hand or the like) into the current, observe that the galvanometer needle, which at first marked a certain degree of current strength, say, 2 ma., will, after a short continuation of the flowing of the current through the object, move forward quite a distance and then mark 3 or 4 ma. I. has become greater, not because E. has become greater, but because R. has become less.

This decrease of the resistance will, of course, continue only until a certain limit is reached (constant minimum resistance). The stronger the currents, the more rapid in general the decrease of the resistance. In old people and in children the initial resistance is often very great in the beginning, and later on, during the passage of the

current, there will be a considerable decrease of the same (see Chapter VI., Conduction Resistance).

Should one desire a particularly great reduction of the resistance of the skin, then, besides a thorough moistening with lukewarm or warm water, a little salt may be added to the water.*

Graduation of Current

When thus the two postulates—(1) the gradual increase of current, and (2) the determination each time of the strength of the current by means of the battery switch on one side and the galvanometer on the other †—are fulfilled, there still remains to be desired the possibility of graduating the intensity of the current more delicately than can be done by the turning of the switch from ten to ten cells (or even from cell to cell).

If—as, for instance, in a case for diagnosis—it is necessary to be able to ascertain that intensity of current which will cause the slightest discernible contraction (minimal contraction) of a muscle, and if for this purpose cell after cell is included into the current, we

* A great reduction of resistance is effected by all so-called current manipulations, closings, openings, turnings, etc. (see further down).

† On most galvanometers there are to be found one or more small accessory apparatus, which may be casually mentioned; a little device, by means of which the oscillating-needle may be excluded or placed at any desired point (through frequent changing or manipulating of the current the needle might easily be misplaced through its too intense swaying back and forth); besides this, a multiplying time device, which enables us easily to calculate greater current intensities than are recorded on the scale. A more detailed description of this little apparatus may be omitted. In Fig. 5 the little block containing the multiplicator is marked *M.* At *M* are stoppers ("shunts"), according to the use of which the amount shown by the galvanometer must be increased, two- or five- or tenfold.

should incidentally see that a current generated by, say seventeen cells, might produce a strong (not minimal) contraction, but that a current of sixteen cells would produce no contraction at all. The minimal contraction, then, lies somewhere between these two.

For therapeutic purposes also, or, for instance, in the galvanization of the head, or the galvanic treatment of neuralgias, it is absolutely necessary to avoid the current changes (see details below) caused by jumping from cell to cell.

Rheostat To do away with these undesirable conditions and to obtain an extraordinarily delicate and gradual variation of the current intensity, we use the rheostat designated by *R* on the table of the apparatus.

The principle of the rheostat is something like that of a sluice placed in a liquid current (river). This sluice opposes a resistance to the further flow of the water, and can be gradually raised out of the current. The higher it is raised, the greater will be the amount of water which will flow with the current.

If we suppose resisting objects to be inserted into the connecting-arc of a cell, for instance, numerous small German-silver rods, in such a way that the current must pass through them before reaching the human body, then the difficulty attending the passage of the current increases with the number of resisting substances placed in the connecting-arc of a cell.

With a certain number of these inserted resistances, no portion of the current will be able to pass through the body. If it is possible to interpose resistance in increasing degrees, then the amount of the current to reach

the body will gradually become less and less. This is accomplished by the rheostat (in direct connection) diagrammatically presented in Fig. 6, and in Figs. 4 and 5 designated as *R*. Below the apparatus table are placed German-silver rods, each of which leads to a contact-point on the surface of the table. A handle glides over these points of contact arranged in a circle. When the handle (*C* in Fig. 6) is placed on the first

Rheostat in Direct Current

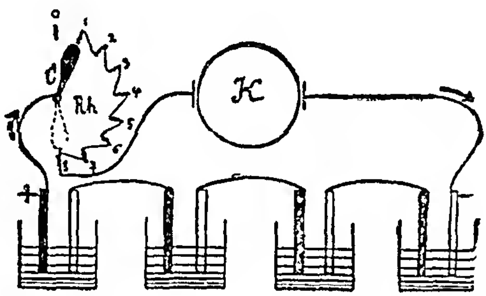


FIG. 6.—The Rheostat in Direct Connection. *Rh*, Rheostat; *C*, handle; *K*, human body.

point of contact to the right of *O* (which would be upon the contact-point 1 in Fig. 6 *), then we see that the current would have to pass through all the little German-silver rods before it can reach the body. These little rods offer so much resistance to the circuit that when the handle is placed thus no current can reach the body; no matter how many cells have been included by means of the battery switch, the needle of the galvanometer remains fixed. But if we now turn the handle around to the right, less and less resistances will remain to the circuit, more and more resistances will be excluded, so

* There is a break at contact *O*.

that the passage becomes clearer and clearer for the current, and gradually more and more current can pass into the body; and when the handle—the dotted line in Fig. 6—rests on the last point of resistance (*8* in Fig. 6), then the entire current will pass through the body unhindered.

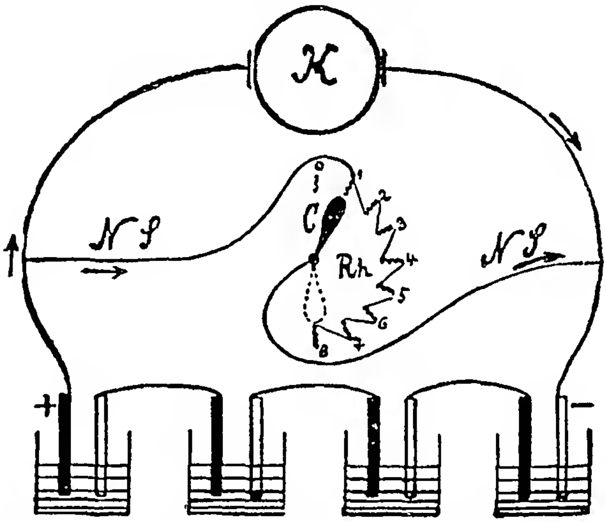


FIG. 7.—The Rheostat in Accessory Connection. *NS*, Accessory connection; *Rh*, rheostat; *C*, handle; *K*, human body.

This gradual increase in the intensity of the current is obtained by moving the galvanometer needle slowly and steadily forward from the *0* point.

Rheostat in Accessory Connection

The principle of the rheostat in the accessory connection is not much more complicated (see Fig. 7). If, namely, a second connection (accessory connection) is brought into the connecting-arc of a cell—*NS* in Fig. 7—and the human body is in the first connecting-arc (direct connection), then the current could pass along two ways—through the direct connection with the human body, or through the accessory connection. Now the current usually selects the most convenient path, and, since the human body, as we saw above, offers a strong resistance to the current, therefore, when

a metallic accessory connection is arranged at the connecting-arc of the cell or of the battery, at that very moment the entire current of the cell or of the battery will select the easier path through the accessory connection, and, comparatively speaking, nothing will pass through the body. Now let us remember that resistance is also present in the accessary connection, for instance, that of numerous small German-silver rods, so many that their resistance is greater than the resistance of the body; therefore the path through the direct connection will be relatively easier for the current, and the entire (or almost the whole) current of the battery will pass through the body; and if, finally, there exists the possibility to include the resistances one after another into the accessory connection, the passage through the accessory connection will gradually become more and more difficult and the path through the direct connection more and more easy, and after a while less and less of the current of the battery will pass through the accessory current and more and more through the body.

The rheostat in the accessory connection, constructed according to this principle, is diagrammatically represented in Fig. 7. When the handle *C* of the apparatus, which is outwardly similar to the other rheostats, rests on contact-point 1, then this means (as can be easily seen from the figure) that no resistance worth speaking of is in the accessory connection. Almost the entire current now passes through the accessory connection; hardly any cells are included in the current by means of the cell-connecting switch; hardly any current at all reaches the body, the galvanometer needle pointing to *O*. When the handle is slowly turned to the right, an increasing number of resistances are gradually being inserted into the accessory current, and the passage for the current (as stated above) becomes, relatively speaking, easier through the direct connection, and there is a very gradual increase in the intensity of the current in the body, the point of the galvanometer needle slowly moving away from *O*.*

*The modern apparatus fitted with Leclanché cells have the rheostat in the direct connection for the purpose of saving the current. What follows will constantly assume this connection.

Use of Rheostat

How, then, do we employ the rheostat? When, for instance, we wish to determine the amount of current strength necessary to bring about the minimal contraction of a muscle, we must proceed in the following manner: Place the moistened electrodes upon the muscle (details concerning the arrangement of electrodes will follow later), include any desirable number of cells (ten, twenty, etc.), while the rheostat handle rests at *0*. Then slowly move the handle of the rheostat along the points of contact until a distinct contraction of the muscle is observed at an opening or closing of the current (see below). Now, while the current remains closed, look at the galvanometer needle and read the intensity of the current in ma. from the scale.

Or if we wish to undertake for therapeutic purposes, for example, a galvanization of the head, with a certain lesser current strength, say 1 ma., we again apply the moistened electrode (in a manner the details of which are to be described later) to the head of the patient, and include any desired number of cells, and now, while continually observing the galvanometer needle, we slowly turn the handle of the rheostat clockwise (to the right), until the needle marks 1 ma.*

Current Reverser

Still another accessory apparatus, which is of impor-

* Consequently it is not of so much importance, in the regulation of the current strength, how many cells are used; the regulation is done by the rheostat, not by the cell-connecting switch. But, as a matter of course, the gradation may be much more delicate, if (for instance, to obtain weak currents) a small number of cells are included so that the entire rheostat may be used for current graduation. See above, footnote, page 12.

tance in the application of the galvanic current, must be briefly described here—the current reverser, designated by *R* in Fig. 5. This is used to change easily the direction of the current in the connecting-arc without disturbing the electrodes, a condition that is almost indispensable for purposes of investigation. When the handle of the reverser rests on the contact-point *N* (normal position), it shows that the current is flowing in the original direction, that is, from the + binding-post to the −

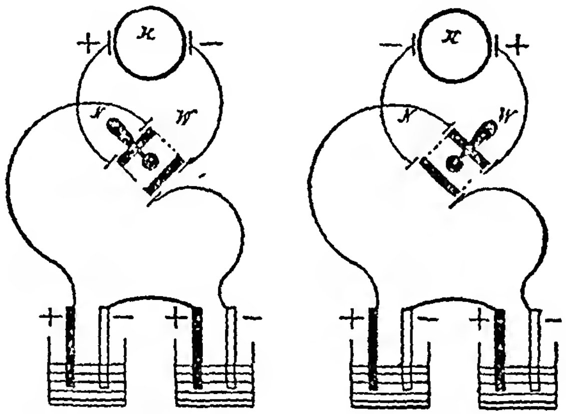


FIG. 8.—The Current Reverser. *N*, Normal point; *W*, reversed point; *K*, human body.

binding-post; but if the handle is moved to *W* (turning-point), there the + binding-post is the kathode and the − binding-post is the anode, and the current direction goes from the latter to the former—that is, in the opposite direction.*

* Between *N* and *W* there is a point upon which if the current reverser rests the circuit is open. By turning this reverser, therefore, it is possible to open or close the circuit in one direction or the other at will.

In the discussion in the course of the investigation, it will be necessary to refer to this apparatus. The principle of its technical arrangement is a very simple one, and is illustrated by the diagrammatic figure (Fig. 8), in which the parts drawn in black are metallic and the dotted parts are non-conducting hard rubber.

Current in Galvanic Apparatus

In like manner, with the aid of the following figure (Fig. 9), the current direction in a galvanic apparatus is easily understood without further explanation.

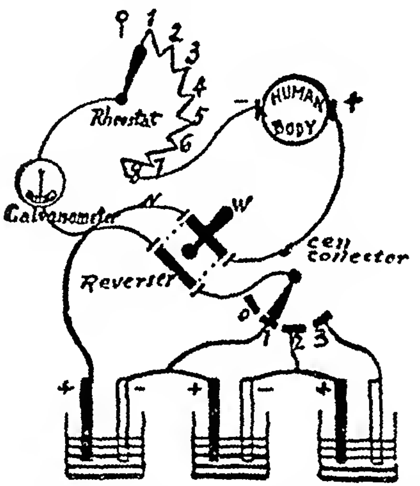


FIG. 9.—Diagram of the Current Course of a a Galvanic Apparatus.

The current leaves the battery (according as the cell-collecting switch of the current consists of more or less cells) through one side of the current reverser, and then passes at the point *W* to the body, then to the rheostat, then to the galvanometer, and then through the other side of the current reverser and the cell-collecting switch, back to the battery. (At *N* a corresponding change in the current direction takes place.)

B. The Faradic Apparatus.

The Induction Current

We enter upon the discussion of the faradic apparatus, starting again from the simple galvanic cell. We can give the metallic connecting-arc any desired form, as, for example, a spiral. If now this spirally formed

connecting-arc is rapidly brought near to another metallic electrical conductor, as, for example, a second spiral, a galvanic current will also occur in this second spiral at the moment of its approach (this is the law of the so-called induction), and when the second spiral is rapidly withdrawn from the spirally formed connecting-arc of the galvanic cells a galvanic current again occurs in the second spiral. The spirally formed connecting-arc of the cell is called the primary spiral (*P.S.* in Fig. 10), and that of the second spirally formed metallic conductor is called the secondary spiral (*S.S.* in Fig. 10). The current which occurs in this way in the secondary spiral is opposably directed in the rapid approach of the primary galvanic current, and similarly directed in the rapid withdrawal. We call this induction, faradic or secondary current.

Use of Faradic Apparatus

The rapid approximation of the secondary and primary spirals to each other and their rapid separation

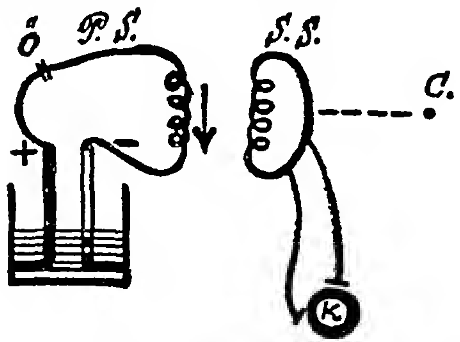


FIG. 10.—*P S*, Primary spiral; *S S*, secondary spiral; *O*, point of interruption; *C*, imaginary rotation point; *K*, human body.

may be accomplished by allowing the secondary spiral to rotate on any given point, *C*, or—and this is the case

in all medical inductive-apparatus—by allowing the secondary spiral to remain stationary, but introducing an interrupting-device into the connecting-arc of the primary spiral at any one point (*O*), and here continually, rapidly closing and opening the current of the primary spiral. Then this will approximately correspond to a continual and rapid approach of both spirals from infinite distance and a rapid separation to infinite distance. The quicker this alternate closing and opening of the current in the connecting-arc of the galvanic cells occurs, the more intensive will be (*ceteris paribus*) the induction effect upon the secondary spiral, in which two continually changing currents will then occur, one of which will always be opposed to the primary current and the second of which will always correspond to it.

Wagner-Neef Hammer

The rapid closing and opening of the primary current, repeated many times in a unit of time, will be shown in our induction-apparatus by means of the Wagner-Neef hammer (Fig. 11).

Concerning the use and construction of the induction-apparatus, note particularly the following: A metallic connecting-arc (of heavily insulated copper wire) goes from one or two of the ordinary galvanic cells (*E*, Fig. 11), to be found under the apparatus table, to the top of the table-plate, and is there spirally wound a few times around a wooden cylinder (primary spiral, *P.S.*). At a distance (regulated by means of a cog-wheel arrangement and a vertical screw) from this primary spiral is a second cylinder wound about with many coils of finer wire, with a greater diameter than the first and hollow like a tube, in order that the primary cylinder may be enclosed in it (secondary spiral, *S.S.*).

Furthermore, at the primary coil (that is, the connecting-arc of

the cells) we find an iron rod (*M*) enclosed in the wire of the connecting-arc. A metallic plate (anchor, *A*) hangs over this iron rod, and is maintained in this swinging position by a spring (*F*) at the primary spiral. Now if one of the openings (*O* in Fig. 11) in the block *J* (Fig. 5, page 9) upon the table be plugged, immediately a galvanic current will occur in the connecting-arc (that is, the primary coil) which has until now been open. Because of the occurrence of this current, this insulated iron rod (*M*) becomes magnetic at the same time, and it forcibly attracts the metallic plate (anchor, *A*) suspended over it. At the same time this frees the metallic plate

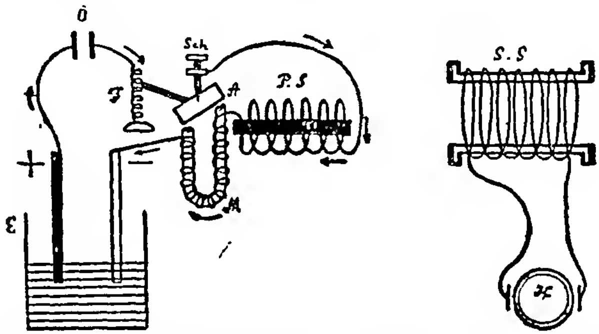


FIG. 11.=Diagram of Induction Apparatus. *E*, Cell; *O*, opening in the primary current circuit for plug; *F*, spring; *Sch*, screw; *A*, ancher; *M*, magnetic iron rod of the hammer; *P S*, primary spiral; *S S*, secondary spiral; *K*, human body.

from its connection with a superimposed small screw (*Sch*). By the loosening of this connection between screw and plate the circuit is broken; and when that happens the iron rod loses its magnetic power, and the spring by means of its own elasticity draws the metal plate (*A*) toward it and away from the formerly magnetic iron rod. In this way the plate again comes into contact with the screw, the circuit is again closed, the iron rod again becomes magnetic, etc.

This play of the hammer, which is exceedingly rapid, occurring many times in a second, produces the well-known buzz of the faradic apparatus; as soon as we close the current by plugging up the block (see Fig. 5, *J*), we cause, many times in a second, an alternate recurrence of two currents in the secondary coil, flowing in oppo-

site directions (alternating currents), which may be conducted from this coil to the human body.*

Manipulation

In all apparatus, as has been stated, the secondary coil (which, as we know, is tubular) may be moved over the cylindrical primary coil.† The farther it is removed from the primary coil, the weaker is the induction effect; the latter will be at its maximum when the secondary coil completely surrounds the primary coil, that is, when the coil distance (*C.D.*)—which may be read from a centimeter scale placed on the table—is exactly *0*.‡

*E. Remak has presented a small "apparatus for the production of single-stroke induction," which makes possible "a current-closing of the induced current, solely by means of the primary coil, in which the Wagner-Neef hammer is not considered at all."

† An iron core inserted in the primary spiral, which is magnetized by the primary current, serves to strengthen this primary current, and consequently to strengthen its induction influence upon the secondary one also. If it be drawn out, the primary as well as the faradic current becomes weaker; the farther it is inserted, the stronger will become both currents.

‡ What we read from the scale is—as is easily seen—not the current strength (I.) of the secondary current, for we do not know the resistance (R.), and an absolute measuring apparatus, by means of which we could read I. (as in the absolute galvanometer for the galvanic current), does not yet exist. The body and skin resistance does not play by far as important a part for the faradic current as it does for the galvanic current. But for the computation of the electromotor force (E.) of the apparatus, at least, it would be of importance to have a device by means of which it would be possible directly to read off the actual strength in standard units, as, for example, in volts, so as to be able to compare the results of different apparatus or of the same apparatus at various times, all of which, with the difference in construction of the various apparatus and the variation in sensibility, is impossible without such a device. The so-called faradimeters are constructed upon this principle, but they have not been very favorably received. Perhaps an apparatus recently invented by Hoorweg, which, it is said, makes possible (as

The Faradic Pole

The continual changing of the current direction of the secondary spiral, repeated many times in a unit of time, will naturally result in the poles also continually changing their positions: that which is the anode in the first fraction of one second becoming the kathode in the next. We can not, therefore, really speak of a faradic anode and kathode, as we distinguish them in the constant current, and as a matter of fact in therapeutic practise we do not usually make a distinction.*

with the galvanometer) the reading of the current intensity, will be more successful.

*But the fact remains that there is a difference between the faradic poles, for the following reason:

Just as the primary spiral has an induction effect upon the secondary spiral, so the separate windings of the primary spiral have a sort of induction effect upon each other (self-induction). Upon this in the primary spiral itself a current called the extra-current occurs at every momentary opening and closing caused by the Wagner-Neef hammer, and just as in the current of the secondary coil, so also in this extra-current of the primary coil, the current direction at each momentary closing is opposed to the primary current, and at each momentary opening is the same as in the primary current. At every momentary closing, therefore, there are always two currents in the primary coil at the same time—(1) the primary, (2) the extra-current—which are opposed to each other; but through this opposing direction the extra-current retards and weakens the primary, and therefore in the momentary closing the induction effect of the primary coil upon the secondary, and in like manner the secondary current itself, are relatively weak. In the momentary opening the primary current disappears, each time through the opening; but at this phase a strong extra-current, its expanding strength unhindered, arises, having the same direction as the disappearing primary current and the secondary current generated by its disappearance. Hence at every momentary opening the induction effect upon the secondary coil, as well as the secondary faradic current itself, will be very strong. If these differences in strength between the opening and closing currents are great enough—and that

The Current-Changer

In all stationary and in many portable apparatus, there is still another device which may be described in a few words. This is the current-changing device constructed upon de Watteville's plan (*S* in Fig. 5).

It is very desirable, for purposes of investigation, to be able to send (in the same course) the faradic current into the body, from the same pair of binding-posts from which the galvanic current is conducted, through the conducting-cords and the electrodes to the body.

This may be done with the aid of the current-changer, when we move the handle, which is usually at *C* (constant current) to *S* (secondary current). If now we close the circuit of the primary faradic current by plugging the block at *J* (in Figs. 5 and 12), we can,

is usually the case—we may, for practical purposes, ignore the weak closing current entirely, and to a certain extent may regard the induced current as consisting of a series of opening currents. These opening currents all have, as we have just seen, the same direction —*i.e.*, the same as the primary current; therefore, if we maintain this statement of the single current direction, we can again (in the same way also) distinguish an anode and a kathode of the faradic current. By this we mean the anode and the kathode in the position they would have if the faradic current were nothing more than a series of uninterrupted opening currents. We shall see later on that these differences between the faradic poles practically will occasionally be of the highest importance.

In most apparatus, furthermore, we can also turn off the extra-current (or "primary induction-current," as it is also called) directly; now as this must, to a certain extent always, give off a part of its strength to the secondary coil, it will be strongest the more strength it can save, *i.e.*, the further the secondary coil is removed from it, and weakest when the secondary coil has approached as close as possible; that is, when the coil distance = 0. We strengthen it, therefore, by removing the secondary coil, or—better and more exactly—by the insertion of the iron core which had been removed (see page 26, footnote).

from the same binding-posts which before transmitted the constant current, now conduct the induced current, always provided that the rheostat is not at *0*, because then no current will reach the body. We can, therefore, if we wish to increase the strength of the faradic

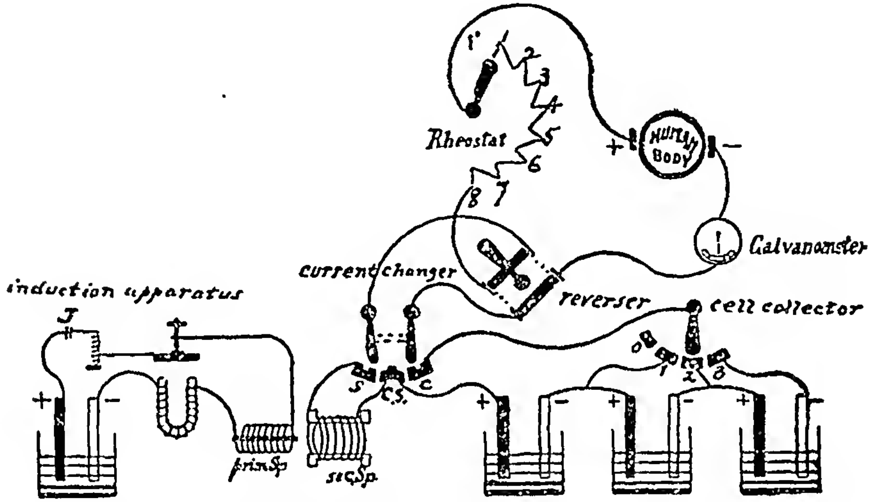


FIG. 12.—Diagram of the Current Course, in the previously described (Figs. 4 and 5, pages 8 and 9) stationary apparatus—for the constant and induced currents—the galvanic on the right, the faradic on the left. Both apparatus have been already shown diagramatically in Figs. 9 and 11. In the middle of the figure there is the de Watteville current-changer. By placing the handle of the current-changer at *C*, the galvanic current passes into the body; by placing it at *S*, the current of the secondary spiral so passes; by placing them at C.S. both currents pass simultaneously into the body. We see also that both currents, the constant as well as the secondary, must go through the current-reverser and the rheostat before they reach the body. At *J* is the little block with plug; through the introduction of this the primary current is produced and the Neef hammer starts into activity.

current, by moving the current-changer, accomplish it in two ways: either we fix upon any desired coil distance (*C.D.*), and then, as in the galvanic current, gradually turn the handle of the rheostat to the right, allowing more and more of the current to pass through the body;

or—and this is the more convenient way—we exclude the rheostat altogether by turning the handle completely around the clock-dial device to its non-resistance point, so that now the entire current of the faradic apparatus can immediately reach the body, and we regulate the strength of this current by moving the secondary coil over the primary. The strength of the faradic current employed each time may then be read from the graduated scale, as mentioned, in centimeters or millimeters *C.D.* We must, therefore, through the medium of the current-changer, if we wish to transmit the faradic current from the same pair of binding-posts of the galvanic apparatus, employ the following manipulations: (1) Turn the changing-handle from *C* to *S.* (2) Exclude the rheostat (direct connection) by turning the handle to the last contact-point. (3) Plug the block and regulate the current strength by moving the coils.

The contact-point, *CS,* of the current-changer makes possible the simultaneous transmission of the faradic and galvanic (combined) currents from the same pair of binding-posts. A more detailed explanation will be found in the discussion of therapeutics (compare also Fig. 44).

Once more we shall have to turn to Ohm's law: $C. = \frac{E.}{R.}$

Density

We must always be able accurately to determine the current strength of the galvanic current in the body, and this we do when we read it directly from the galvanometer; but it is not so necessary for our diagnostic and therapeutic purposes to know the strength of the

current preseut in the body. Above all, we wish to know how great is the effect which the current exerts, iu a concrete case, on a given part of the body; that is (in diagnosis) the stimulating power on the excitation-point of a muscle, or (in therapeutics) the healing effect, *e.g.*, the effect ueeded to reduce the excitability of a painful point, etc. This action evidently does not depend upou the current streugth aloue, but upon the coucentration, *i.e.*, the density, with which a current of given streugth reaches the desired point. Suppose, by way of example, a certain current strength of 3 ma., passing through the body in such a mauner that it passes two plate-like electrodes of 100 sq. cm. diameter; one of these electrodes may be placed on the sternum and the other on the ball of the thumb of the hand, the muscles of which we wish to examine. Now the galvanic current has the known property, in favorable electrical conductiug media, to expand. We may imagine it to be composed of parallel current threads. These threads lie very close to each other in the metallic connectiug-arc of the cell of the battery. In the broad electrodes, in which they equally gaiu space, they spread themselves iu all directions. Since the area of the electrodes of 100 sq. cm. is much greater than the area of the ball of the thumb, therefore from (hypothetical) current threads only a greater or less fraction reaches the excitation-poiut of the selected muscle of the ball of the thumb. Again, if we leave the large plate electrode on the sternum, and apply an electrode of very small area, *e.g.*, one of 3 sq. cm., on the ball of the thumb, then all or nearly all of the

Diameter of Electrode

current threads will reach the excitation point of the muscle. The effect which such an equally concentrated current exerts, in the last-mentioned case, on the selected muscle will naturally be disproportionately greater than the effect of the application of the large plate in the first example, despite that in both cases the current strength was the same, 3 ma. Thus the effect of a current, its stimulating effect on a muscle or nerve, like every other effect does not depend upon the current strength alone, but upon the density as well. This density (D.) will be greater, *ceteris paribus*, the greater is the current strength, I. It will also depend, as we have just seen, upon a second factor, namely, upon the size of the diameter of the connecting-arc, that is, the electrode diameter, Dia. The greater this diameter, the smaller it will be, and vice versa. $D. = \frac{I.,}{Dia.}$, the density is equal to the current intensity divided by the diameter. Since for us the density, as has been said, is the expression of the effect of the current, we must in every case recognize and determine it. This calculation is very simple, for we can read I. directly from the galvanometer, and read the diameter expressed in square centimeters on the handle of each electrode.

CHAPTER II

THE LAWS OF CONTRACTION AND OTHER INTRODUCTORY PHYSIOLOGICAL OBSERVATIONS

THE physiological facts which are shortly to be discussed depend upon the galvanic current alone.

As has been stated already, when a galvanic current of a certain strength reaches a muscle, it acts as a stimulant to this muscle, and the muscle contracts. This is direct muscle stimulation.

When a galvanic current of a given strength reaches a motor nerve, it stimulates the latter as well, for the muscles supplied by this nerve contract. This is indirect muscle stimulation. Muscle Contraction.

This contraction of the muscle or muscles usually* does not continue during the entire duration of the current passage through the muscle or nerve; it occurs only:

1. When the current enters (current closing).
2. When the current is withdrawn (current opening).
3. When the current is suddenly strengthened.
4. When the current is suddenly weakened.
5. When the current direction is suddenly reversed (current reversing).

In a word, the stimulation of the muscle or of the nerve occurs only with current manipulations. In the

* For exception, see page 42.

Dubois-Reymond's Law

law named after him, Dubois-Reymond has formulated this as follows:

It is not the absolute strength of the current, at any given moment, that stimulates the muscle or motor nerve, but the variation in its strength. The greater and the more sudden these changes are, the greater is their stimulating power. They are usually greatest during the opening and closing of the current.

Experiments on animals have shown:

(1) That the different current manipulations work in different ways, that is, closing the current has a different effect from opening it; (2) that weak currents have not the same effect as strong ones; and (3) that the direction in which the current flows through the motor nerve and reaches the muscle makes a great difference in the stimulative effect—a matter of chief importance.

Pflüger has instituted investigations on animals and has formulated these investigations in the contraction law which has been named after him.

Altho this law holds absolutely true only for experiments on animals, and thus can not be transferred outright to human conditions, still it will be discussed here, first, because by means of it we can more easily understand the conditions of human contraction, and second, because later, in electro-therapeutics, we must return to the results discovered by Pflüger and other later physiological investigators.

Pflüger's Law

Pflüger examined the uncovered ischiadic nerve and its associated gastrocnemius muscle, applying the two electrodes of a galvanic battery to the two ends of the nerve in two different ways. First, the anode (An.) was placed on the central nerve end, the kathode (Ka.) on the peripheral, the current therefore flows from the An.

to Ka. in the direction of the innervating descending current (↓). Second, the arrangement was reversed: An. at the peripheral end, Ka. at the central end; the current therefore flows (from An. to Ka.) against the innervating ascending current (↑). In both of these current directions there should be tried the effect of closing (Cl.) and the effect of opening (O.) the current. Because it was further found that the effect of the current varied according to the current strength, all the instances mentioned were tried with three degrees of current strength: current strength i. (weak), current strength ii. (medium), and current strength iii. (strong). Pflüger,

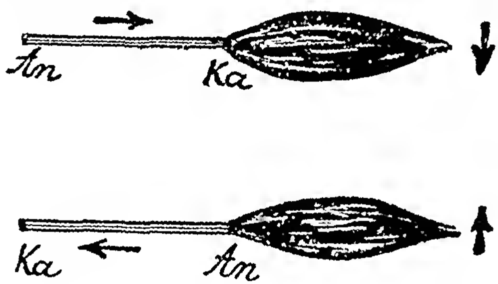


FIG. 13.

in this investigation, therefore laid stress on the three following facts: (1) the current direction, (2) the kind of current manipulations (closing or opening), and (3) the current strength.

Expressed in formulæ and words, in which + always = contraction, and 0 = no contraction, Pflüger's law, which is based on his experiments, is as follows:

	↓ ↑	
i.	Cl. + + O. 0 0	With weak current, contraction occurs with the ascending as well as with the descending current, only at the closing.
ii.	Cl. + + O. + +	With medium current, contraction occurs as well with the ascending as with the descending current, at closing and opening.
iii.	Cl. + 0 O. 0 +	With strong current, contraction occurs with the descending current direction only at closing, and with the ascending only at opening.

Electrotonus

The explanation of these discoveries was given after later investigations in the following way:

1. During the time that the galvanic current affects a nerve, there occurs an internal change in the condition of the nerve, namely, its excitability changes, so that in the vicinity of the kathode (Ka.) there is a condition of increased, and in the vicinity of the anode (An.) a condition of decreased, excitability. We call this change of excitability electrotonus—the increased excitability at the Ka. kathelectrotonus, and the decreased excitability at the An., anelectrotonus. The stronger the influencing current, the stronger will be these differences in excitability. This lasts the entire time during which the current flows through the nerve.

2. The kathelectrotonus, which occurs at the closing of the current (and with very rapid increase in strength), acts as a contraction stimulation on the nerves and on the associated muscle at the point where it occurs, that is, at the Ka. Therefore a contraction occurs at every circuit closing, with ascending or descending currents, of any current strength (the exception for ascending currents of strength iii. will soon be explained).

3. With every current opening there occurs in the nerve a sudden reversal—negative modification—of the electrotonic (excitation) condition, that is, the anelectrotonus disappears with every opening at the anode (An.), and a very transitory condition of increased excitability occurs there, while, on the contrary, at the kathode (Ka.) there is a short condition of decreased excitability. This disappearance of the anelectrotonus and the negative modification likewise act as a contraction stimulant, but not nearly so strongly as the kathelectrotonus. With weak currents (strength i.) the strength of this phenomenon is not sufficient to cause a contraction; therefore at the opening of the current (strength i.) we see no contraction occur. It is different with current strength ii., where at every opening, as well with the ascending as with the descending current, the stimulation of the disappearing and the reversed anelectrotonus causes a contraction.

4. With current of strength iii. (strong currents) the conditions

differ only quantitatively from the above. In that case the electrotonic differences of excitability are so great that, while an extraordinarily great excitation is produced at the kathode, the excitation at the anode is practically extinguished. The point at the anode (An.) becomes almost entirely inexcitable and non-conducting with these strong currents.

If we think of Fig. 13 modified in such a manner that the electrotonic changes are indicated by curves (see Fig. 14), the increased excitability at the Ka. by a high curve above the line, the decreased

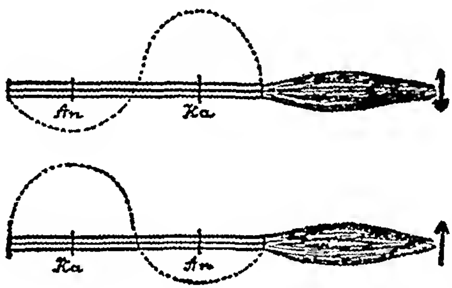


FIG. 14.

excitability at the An. by the lower curve under the line, we can at once perceive from the figure the explanation for the third part of Pflüger's law.

With the closing of the descending current there occurs a stimulating effect at the Ka. (forcible contraction); with the opening a stimulating effect at the An., but before the stimulation reaches the muscle it must pass a point at the Ka., which, because of its very strong negative modification, has become inexcitable; it can not conduct the stimulation, and therefore no contraction can occur. With the ascending current the case is reversed, as is easily seen from the figure. Hence with it no contraction takes place at the closing, but a strong one at the opening.

Pflüger's law can not be applied to the human body without modification (as was stated above) for several reasons, one of which may be presented here (after Erb).

Since, with the human being, the poles can not be placed on the naked nerve, the nerve itself, the current travels from pole to pole, not through the nerve, but first through the skin, and the human nerve is reached by current streamers only (see Fig. 15), which are formed because the current tries to distribute itself in the well-conducting tissues of the subcutaneous stratum or in the interposed layer of muscular tissue, etc. Thus currents going in different directions strike the nerve at

Current Streamers

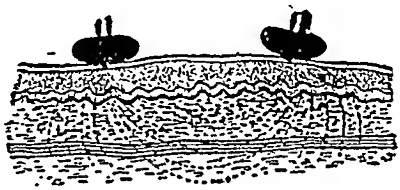


FIG. 15.—Diagram of Section through the Skin. An underlying nerve is met by current streamers, which spread out between the two electrodes placed upon the skin.

different points, so that we no longer have ascending and descending currents, such as play a part in Pflüger's law.

Because of these and other reasons, which need not be mentioned (see Chapter IV. on the "Reaction of Degeneration"), a direct application of animal law to the human body is not possible. Still a certain conformity to the law is present in the reaction of human nerves and muscles to the galvanic current, and here again arise the different effects which occur at closing and opening as well as with different strengths.

To these two factors—namely, (1) the kind of manipulation (closing or opening), (2) the current strength (the current direction, as was said, is not taken into consid-

eration in the human subject)—there is added a third factor which has proved itself significant from Pflüger's law, namely, the different effects of the poles.

The Law of Human Contractility

In order to see how a given pole, An. or Ka., affects a nerve or muscle, it is necessary to make a very particular and special method of investigation.

It is clear, *a priori*, that it is theoretically impossible to have only one pole of the galvanic current on a muscle or nerve; in every arrangement the other pole (however distant) always produces an effect, even tho often only a weak one. The significance of the special arrangement which is to be discussed must be taken *cum grano salis*, and the results attained with it are to be considered only as sufficiently exact for practical use.

It consists in choosing two electrodes of very different diameters, *e.g.*, one of 100 sq. cm., the other of 3 sq. cm. Then the concentration at the small electrode, and therefore also the stimulating power of the small electrode, will be very great, and the concentration and stimulating power of the larger plate will be so very small that practically it may be left entirely out of consideration. Especially will this be the case if the small electrode is applied directly over the muscle to be examined, *e.g.*, the upper part of the cucullaris muscle, while the large plate is applied at a distant point, as, *e.g.*, on the sternum. In such an arrangement we call the large plate the indifferent electrode, because its stimulating effect on the muscle in question is practically insignificant; the small plate which is placed over the muscle itself we call the different or exciting electrode.

If we arrange the electrodes so that we apply the small

electrode over any muscle or motor nerve, and—most conveniently by means of the current reverser—change this exciting electrode now to the Ka., now to the An., we can in a certain measure examine the muscle with only one pole (monopolar examination). Then we can test the effect of the galvanic current with the positive and the negative pole separately.

In order to test the effect of different current strengths, we may easily regulate the current strength of the galvanic apparatus by means of the cell collector and the rheostat (and read it from the galvanometer).

The Interrupter

Finally, in order to determine in a simple manner the separate effect of closing and opening, we use a small

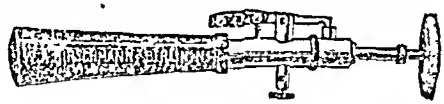


FIG. 16.

arrangement which is attached to the handle of many electrodes—the so-called interrupter. With the help of this interrupting electrode, closing and opening can be effected at any time with the electrode stationary, by means of a simple pressure of the finger.

Meyer's interrupting electrode (see Fig. 16) has, between the connecting-screw and the electrode surface, a non-conducting hard-rubber plate. At the side of the electrode we find a metal lever, which may be lifted by pressure on a small spring, and which on release of the pressure falls back. If we press the spring down with the thumb and thus lift the metal lever, no current can reach the surface of the electrode through the non-conducting rubber; the circuit is open. If the thumb is lifted from the spring, then the lever touches the electrode handle between the electrode surface and the

rubber plate, and now the current can reach the surface of the electrode by going around the rubber plate through the metal lever; then the circuit is closed. Thus, without having to remove the electrode from the point at which it is applied, by thumb pressure and release of pressure we can produce circuit closing and opening.*

Test of Law of Human Contractibility

To test the human polar contraction law, we apply a large moistened electrode plate on the sternum; a small one, 3 sq. cm. in diameter, also moistened and provided with an interrupter, we apply closely to any motor nerve or muscle of the body, *e.g.*, to the upper portion of the cucullaris muscle; include a desired number of galvanic cells (twenty or thirty or some such number), gradually strengthening the galvanic current by means of the rheostat; and open and close the circuit with the interrupter. Then we shall notice the following, which may be presented in the table below, expressed in a manner analogous to Pflüger's formula.

		An.	Ka.
I.	Cl.	—	C.
	O.	—	—

With weak currents a muscle contraction occurs only when the exciting electrode is the Ka., and only at the instant of the closing. During the passage of the current no contraction is noticeable; nor is there at the opening or when the exciting electrode is the An. We express this briefly thus: With weak current there occurs only a small kathodal closing contraction (Ka.Cl.C.).

		An.	Ka.
II.	Cl.	C.	C.
	O.	C.	—

With stronger, about medium-strength currents, the closing contraction with the negative as exciting electrode, the Ka.Cl.C. becomes greater; but now contraction occurs also when the An. is the exciting electrode, and as well at the closing as at the

* We can also close and open the circuit by means of the current-reverser (see page 21); with the faradic current also (but poorly) by lifting and replacing the electrode.

opening. With medium currents there occur beside a Ka.Cl.C. an anodal closing contraction, An.Cl.C., and an anodal opening contraction, An.O.C. On the other hand, we see no contraction at the opening, with the Ka. as exciting electrode.*

An. Ka.
Cl. C. Te.
III.
O. C. C.

Only with strong currents, in which the An.Cl.C. and the An.O.C. have become quite great, and a very strong contraction occurs with Ka.Cl., which continues tetanically during a part or the entire time of the circuit closing—kathodal closing tetany, Ka.Cl.Te. This is an exception to Dubois-Reymond's law—however, with currents of great strength we can often demonstrate a small Ka.O.C.

Briefly summed up, then, the human contraction laws, expressed in the above abbreviations, would read as follows:

I. Ka.Cl.C.

II. Ka.Cl.C., An.Cl.C., An.O.C.

III. Ka.Cl.Te., An.Cl.C., An.O.C., Ka.Cl.C.

In normal muscle and nerves contractions occur first at the closing of the kathode, later anodal contractions, and last of all kathodal opening contractions; or, as we may say in short, disregarding the Ka.O.C. as practically insignificant—the Ka.Cl.C. is normally greater than the anodal contraction (both caused by the same current strength).†

The Form of Galvanic Contraction

The succession in which the separate factors of excitation (Cl. and O.) occur, with changing current strength and changing poles, being thus determined by the con-

* In most muscles and motor nerves An.Cl.C. occurs somewhat earlier than the An.O.C.; in a minority of muscles the condition is reversed.

† For the physiological exceptions to this rule, see Chapter IV. on Reaction of Degeneration.

traction law, we have still to consider the form of the galvanic contraction. In stimulation of a nerve (indirect stimulation) with the constant current, the normal muscle contracts with lightning-like rapidity. The contraction occurs promptly at the instant of closing or opening, and ceases promptly immediately after it; the muscle relaxes at once.*

At the same time it is immaterial how long the circuit remains closed. However, with very strong currents, as is shown in the contraction law, there occurs at the Ka.Cl. a kind of tetany, that is, continued contraction, which continues for some time or during the entire circuit closing. With currents of ordinary strength the muscle remains relaxed under the continued application of the current. The contraction in direct stimulation of the muscles has the same form.†

The rapidity of the contraction is an uncommonly important sign of the normal nutritive condition of a muscle. Later, in speaking of the reaction of degeneration, we shall recur to this.

One point, however, should be noted here: Variation in the rapidity of contraction occurs even within the limits of the normal.

* Here it may be remarked incidentally that the time between the electrical stimulation and reaction in pathological cases is found to vary. Zanietowski has demonstrated deviations from the normal "conducting rapidity" by means of his "electroneuramobometer."

† That which we call direct stimulation in practise is *de facto* a stimulation of the small nerve branch found in the muscle which it supplies, so that it is really an indirect stimulation also. Only for the sake of brevity will the former inexact expression be retained. The muscle substance itself is also excitable; the tardy contraction in the reaction of degeneration is probably the result of an excitation of the substance of the muscle.

The larger or more massive a muscle is, the more it is stretched or contracted or the greater the point is that it has to move; in short, the greater the weight which it has to work against, the less rapid frequently is the contraction form. *E.g.*, in the small muscles of the face, a contraction generally seems much more lightning-like than in the peroneus longus muscle; and in the quadriceps femoris muscle, again, the contraction is usually more prompt when the leg is lying flat on a support than when it hangs down bent at the knee. In children during the first weeks of life the pathological galvanic contraction is often very tardy. According to my experience, the normal contraction is often remarkably slow in the small foot muscles (extensor digitorum communis brevis muscle, extensor hallucis longus muscle). It is necessary to discover these differences, and also other individual differences in many persons, in order not to jump at false conclusions in pathological cases.

The Faradic Contraction

With the faradic current, for the reason given above (page 27), in practise we use both poles, usually without making a distinction; therefore we can hardly speak of a polar contraction law.

But since, as has been explained above (pages 27 and 28, footnote), as a matter of fact, the amount of the circuit openings of the induced current really concerns us, and we can actually distinguish An. and Ka., and can also show that most muscles react with faradic kathodal stimulation with weaker currents than with anodal stimulation. We can often observe, in the case of muscles that lie in several layers over each other, that the muscles of one layer (*e.g.*, the upper) will answer the faradic Ka., the muscles of another (*e.g.*, the under) the faradic An. We find this frequently on the extensor side of the forearm, *e.g.*, in the extensor carpi radialis longus muscle and the supinator brevis muscle. Even in more extended muscles we often see that other muscle bundles contract with anodal stimulation than with kathodal (the same thing occurs in galvanic stimulation), and that in nerve stimulation different muscles answer the An. and the Ka.

The faradic contraction is tetanic, that is, if we apply the exciting electrode to the muscle (or nerve) and close the circuit, there occurs a forcible contraction of the muscles, which continues as long as the circuit is closed; at the instant of opening the muscle relaxes back to rest.

Since the secondary induction current consists of a number of single, momentary galvanic currents following each other in rapid succession, the muscle responds to each of these momentary currents with lightning-like contraction; and since these currents appear and disappear with great rapidity, and the current fluctuation is very great, and consequently by its excitation effect on the muscle the muscle contraction is very forcible—the momentary single currents follow each other so quickly that before the contraction caused by the first has ceased the next begins. Thus the single excitations accumulate and the contraction appears as tetanic.

The Minimal Contraction and Excitability

Altho so far the qualitative side of the galvanic and faradic muscle contraction has been the sole subject of discussion, now the question as to the quantitative factor of the contraction presents itself: With what current strength does the contraction of a normal muscle first occur? The current strength with which the first just perceptible contraction, the minimal contraction, occurs, is different in different muscles and nerves of the body and even at different points of the same muscle or nerve; moreover, it changes extraordinarily in different individuals and probably even in the same individual at different times, within the limits of the normal. This is true of the minimal contraction caused by the galvanic as well as of that caused by the faradic current.

The minimal contraction is, in general, our measure for the electrical excitability of the nerve or muscle.*

The weaker the current which can produce it, the more excitable is a muscle or nerve; the stronger the current strength which is necessary to produce the minimal contraction, the less is the excitability of the muscle or nerve in question. We measure the strength of the galvânic current necessary to produce the minimal contraction always by means of the galvanometer and read it in milliampères. The strength, or, more correctly, the electromotor force (see page 26), of the faradic current which is necessary to produce it, is measured on the scale of the secondary spiral, and is expressed in millimeters of coil distance.

We must always remember that only the measure for the galvanic current is an absolute one, always and everywhere comparable, and that the faradic measure has only a relative value, depending upon the apparatus used and upon its condition at the time (see page 26).

Variability of Current Strengths

Since the excitability of the muscle and nerve is so very changeable, we can not give a fixed measure which will hold true in all cases, for that which in the contraction law we have designated as "weak," "medium," or "strong" currents are relative values which correspond to quite different current strengths in the different muscles and nerves (see following chapter).

* It is not always so. Despite normal excitability, the occurrence of the minimal contraction may become very difficult as well by reason of the deep position of a nerve or muscle (anatomical variation) as by pathological overlying (edema, thickening of subcutaneous tissue, etc.). For further explanation, see in the fourth chapter sub-head of "Diminutions of Excitability."

General Tests of Excitability

The manner in which we determine the excitability, *i.e.*, the minimal contraction, in a concrete case in the various muscles and nerves to be investigated will be discussed in the next chapter. Here we shall say only this much. If we wish to know if a muscle or nerve has normal excitability, we have two possible ways to determine this: (1) If it is a question of muscles or nerves of one side of the body (supposedly diseased) that we wish to test for their excitability, we have the possibility of comparing them with the symmetrical muscles or nerves of the healthy side of the body. (2) If, however, we suspect an affection of both sides, we must employ a different method to determine whether the diseased minimal contraction occurs with a current of normal strength or not—namely, the comparison with other individuals.*

Stintzing's Tables

Stintzing has followed this method in examining most of the muscles and nerves of the body in a large number of healthy persons with a view to their excitability; from the results obtained he took the average strength of the minimal contractions and arranged them in tables.

* Another method was formerly pursued by Erb: In doubtful cases of double-sided lesions, he suggested comparing the suspected nerve with other nerves of the same individual, because he had discovered that in the same person the different nerves show a certain constant relation in regard to their excitability. (He based his presentations principally on the ramus frontalis of the facial nerve, and on the accessory, the ulnar, and the peroneus nerves.) The nerve, whose excitability showed a variation from this common relative excitability, was considered to be diseased. It is clear that this method is applicable to only a limited number of diseases, and even then is rather inconvenient.

These tables give us the average values, the normal conditions of excitability of almost all the muscles and nerves of the body, and by comparison with these tables we are able to determine whether any discovered excitability is normal or not.

This sentence, to be sure, needs a limitation: (1) Stintzing's values of faradic excitability can not be used outright for purposes of comparison, since they are expressed in millimeters coil distance, *i.e.*, not by an absolute measure, and therefore hold true only for Stintzing's apparatus at the time of his investigation. So we shall always have to modify first the figures of the tables for our apparatus and by our own experiments. (2) The values of the galvanic excitability are indeed absolute and comparable without further change, but their limits are very wide (*e.g.*, peroneus nerve, galvanic excitability from 0.2 to 2 ma.). Therefore it would be possible, if we found that the peroneus nerve in a person reacts to 1.75 ma. on both sides, that this might lie within the limits of the normal; or that, on the other hand, it might indicate a considerable diminution of excitability, *e.g.*, if the peroneus in question formerly had its minimal contraction at 0.2 ma. (3) The values found in children in the first weeks of life for both currents usually exceed considerably Stintzing's maximum values (C. Westphal and A. Westphal). Stintzing's tables are therefore of use—to sum up what has been said—first, for the galvanic current in decided changes of excitability (in slighter changes only with the greatest caution); second, for the faradic current only after

the conversion of Stintzing's values into values for our own faradic apparatus; third, only for adults or for children after the first months of life.

Two of these tables follow here (after Stintzing):

GALVANIC SCALE OF NERVE EXCITABILITY.

According to the lower limiting values.		According to the higher limiting values.		Average.	
1. Mus.-cut. N..	0.05	1. Musc.-cut. N.	0.28	1. Musc.-cut. N.	0.17
2. Accessory N.	1	2. Accessory N.	.44	2. Accessory N..	.27
3. Ulnar N., I..	.2	3. Ulnar N., I ..	.9	3. Ulnar N., I...	.55
4. Peron. N....	.2	4. Mental R	1.4	4. Median N....	.9
5. Median N ...	.3	5. Median N....	1.5	5. Mental R	.95
6. Crural N....	.4	6. Crural N	1.7	6. Crural N.....	1.05
7. Tibial N	.4	7. Peron. N.....	2.0	7. Peron. N.....	1.1
8. Mental R....	.5	8. Zygom. R....	2.0	8. Zygom. N....	1.4
9. Ulnar N., II.	.6	9. Frontal R...	2.0	9. Frontal N ...	1.45
10. Zygomat. R.	.8	10. Tibial N.....	2.5	10. Tibial N	1.45
11. Frontal R...	.9	11. Facial N.....	2.5	11. Ulnar N., II..	1.6
12. Radial N....	.1	12. Ulnar N., II..	2.6	12. Facial N.....	1.75
13. Facial N....	1.0	13. Radial N	2.7	13. Radial N	1.8

FARADIC SCALE OF NERVE EXCITABILITY.

According to the lower limiting values.		According to the higher limiting values.		Average.	
1. Accessory N.	145	1.	130	1.	137.5
2. Musc.-cut. N.	145	2.	125	2.	135.
3. Mental R	140	3.	125	3.	132.5
4. Ulnar N., I ..	140	4.	120	4.	130.
5. Frontal R....	137	5.	120	5.	128.5
6. Zygomat. R ..	135	6.	115	6.	125.
7. Median N....	135	7.	110	7.	122.5
8. Facial N.....	132	8.	110	8.	121.
9. Ulnar N., II..	130	9.	107	9.	118.5
10. Peron. N	127	10.	103	10.	115.
11. Crural N	120	11.	103	11.	111.5
12. Tibial N.....	120	12.	95	12.	107.5
13. Radial N	120	13.	90	13.	105.

CHAPTER III

THE METHOD OF INVESTIGATION

WHEN a motor nerve or muscle becomes diseased, its *reaction to the electric current* changes under certain conditions, and these changes may be:

Quantitative and Qualitative Changes

1. Quantitative: The excitability of nerve or muscle is not normal; it is increased or decreased or lost. These changes may occur (*a*) with the galvanic, (*b*) with the faradic, (*c*) with both currents.

2. Qualitative: The contraction formula or the contraction form shows a deviation from the normal, and indeed the changes in the contraction law can only concern the galvanic current. Those of the contraction form, however, on the other hand, concern (*a*) the galvanic, (*b*) the faradic, (*c*) both currents.

3. Quantitative and qualitative changes.*

* The electrical reflex contractions are not considered among the reaction changes in the above divisions, because they are not of practical importance. It has often been found that in the stimulation of certain muscles, other muscles not stimulated and remote tho on the same side of the body, contract, *e.g.*, face muscles with arm stimulation, arm muscles with leg stimulation. In other cases symmetrical muscles on the other side contract (electromotor allochiria). Also, with stimulation of certain parts of the skin, contraction has been observed in muscle groups far remote, particularly in diseased muscles (R. Remak's "diplegia contraction," etc.). We take it, as has been said, that these phenomena occur as reflex action with the help of the sensation paths. (See Chapter IV., "Reaction of Degeneration.")

Comparison of Reactions

It is necessary, then, in all pathological conditions in which there occur suspicions of alteration to the electrical reaction to determine the latter exactly and to compare it with the normal reaction, in order to determine if anything pathological is present and what it actually is. Therefore we must in such cases determine:

1. Quantitative: The excitability (expressed by the amount of the minimal contraction) of the diseased nerve or muscle, both for the galvanic and for the faradic current.

2. Qualitative: (*a*) The retention or non-retention of the normal contraction formula for the galvanic current; (*b*) the contraction form for both kinds of current.

All the obtained results must be compared with those that are found in the corresponding normal nerve or muscle, that is—as was discussed in the preceding chapter (page 48)—either in the case of one-sided affections with the corresponding nerve or muscle of the other healthy half of the body, or with the analogous nerve or muscle of a large number of other healthy individuals. Above all, they should be compared with the "Stintzing's table of electro-diagnostic limits and average values."

Point of Greatest Excitability

The quantitative excitability of a muscle is not the same at all places on its surface; it is normally usually greatest at the point where the motor nerve branches into the muscle, that is, at the point nearest the surface (the most excitable point), and it decreases the farther we recede from this point (as has been said already on page 43, footnote). It is, in reality, a stimulation of the intramuscular nerve branches.

The most excitable points of the nerve-trunks are the places at which these trunks lie nearest to the surface of the body.

When we compare a suspected muscle or nerve with a healthy one, to achieve reliable results we compare its most excitable points with each other. The position of these points we must therefore know exactly for electro-diagnosis, and also to practise exact therapeutics; so schematic plates have been made in which these points are indicated on the projected surface of the human body. The study of these plates alone does not suffice, however, for practise, because, in the first place, there are almost as many variations in the normal anatomical variation (in relation to position of the muscles, construction of the skin and the skeleton, greater or lesser development of this or that muscle, etc.) as there are individuals. In the case of every such variation the plate leaves us in the lurch. Secondly, in certain pathological cases the most excitable point of the muscle changes its position, so that the muscle in question can not be stimulated electrically at the point indicated in the scheme, but at another point in course of the muscle. Thirdly, where the muscles overlie each other in several layers, *e.g.*, at the extensor side of the forearm, as the result of atrophy those of the upper layer may disappear and the underlying come to the surface. Then when we stimulate electrically that point of the atrophied muscle indicated in the scheme as the excitable point, we see a contraction to be sure, but it is of an entirely different muscle. In such a case the plate may mislead us.

Schematic Plates

A B C of Electro-Diagnosis

To avoid all these sources of error, it is necessary in order to supplement the plate scheme, which is always useful as a starting-point: (1) To recall the anatomical course of the muscle and motor nerves; (2) to know particularly the function of the individual muscles. Then we shall clearly understand the nature and the source of an observed contraction even in the most anomalous case.

The search for the most excitable muscle and nerve points, which comprises the A B C of all electro-diagnosis, and in which an abundant practical exercise is absolutely necessary for the beginner, is carried out in the following way:

General Rules for Electro-Diagnosis

The investigating physician sits or stands in front of the patient in such a manner that the light falls on the part to be examined and on the electrical apparatus (particularly the galvanometer). Good light is the first requirement. We must also arrange that the head or the arm of the physician or the electrode handle does not shadow the part to be investigated. Observation of the minimal contraction is often difficult even in a bright light, so preferably let the physician as well as the patient sit during the investigation. An examination of the leg is most conveniently carried on with the limb stretched out on a sofa or bench or on two chairs placed together, while the physician sits at the side. To examine the posterior side of the lower extremity, we must require the patient to lie on the stomach, or when this is impossible, let him lie on two chairs; he must turn over so that he lies entirely on the side not to be exam-

ined. The trunk muscles may be investigated with the patient standing.

Necessity "to Relax"

The muscles to be tried must not be rigid. We should also arrange that the position of the body—as just now has been observed regarding the leg—makes a relaxed condition possible. We must require the patient, as soon as we observe that the muscle to be examined contracts, from time to time "to relax," and not to hold himself rigid. This rigidity occurs in consequence of a certain awkwardness of the patients, who first must learn how to relax. Not only hysterical or neurasthenic but also healthy people often do not know how to relax an arm. We can often accomplish this reaction more easily by placing the arm, head, or other part on a rest, or by supporting it with the hand of the physician, or by diverting the attention by counting, etc.

The physician should be careful, in supporting the part to be examined, not to cover it with his own thumb or to hold it in such a way that he can not properly observe the expected effect on muscle or nerve. (In the cases in which the rigidity may be traced to pathological sources—that is, for example, to contractions—certain small manipulations are necessary.)

The Indifferent Electrode

Apply the electrodes moistened. We place an indifferent large plate (see Fig. 30) either on the sternum or on the nape of the neck or on the sacrum. We should during an investigation never place the indifferent electrode in the hand of the patient, because this makes all exactness impossible. Only in cases of necessity should we place the indifferent electrode on the nape of the neck

for diagnostic purposes, because in this position during the application of the galvanic current even with small current variations there occur other effects of this current (such as lightning-like flashes before the eyes, galvanic taste on the tongue, dizziness, etc.), much more easily than when the indifferent electrode is placed on the sternum or on the sacrum. Both of the last-named points, because of the absence of muscle, are also very useful as places for the indifferent electrode. In examining the arms we should hardly select the sternum as the point for placing the indifferent electrode, in order to avoid having the patient use one of his arms to apply the electrode. We choose an exciting electrode of small surface, because thus we attain the greatest possible current concentration. The Exciting Electrode

In order to have a division which can be used conveniently in the fraction $\frac{\text{I.}}{\text{Dia.}}$ (which as we know expresses the current density which we must determine in each case), we may use an exciting electrode of 10 sq. cm. diameter (Erb's normal electrode). We may use it for making examinations; or, since this is too large for many places—for example, on the face—we may use an electrode of 3 sq. cm. diameter (Stintzing normal electrode). We apply the electrode—moistened, of course—squarely, not on the edge, because otherwise the diameter, and, as a consequence, the density, changes. In applying it the physician should always press down the interrupting-handle of the handle, then the interrupter is open. Normal Electrode

Method of Procedure

Now turn on the current, and, first of all, in the search for the most excitable point, use the faradic current, which incidentally is the best also for practise. As the faradic contraction is tetanic, it generally continues longer than the galvanic, throughout the entire duration of the current closure. Since, therefore, its duration can be easily lengthened at the pleasure of the investigator, it will be easier in using the induction current to observe the effect exactly, and therefore also to determine what muscle or nerve we are examining and where its most excitable point lies.*

We begin then with a weak current of the faradic apparatus, close and open the interrupter of the applied electrode time and again; we increase the current by moving the secondary over the primary spiral, until plainly observable contractions occur. Keep the current closed in the single interruption only as long as is absolutely necessary to see the contraction which the faradic current causes, and avoid thereby prolonging the pain which is caused by induction currents of any strength. Places are often particularly sensitive where the bone is immediately under the skin—*e.g.*, on the forehead or at the ulnar and peroneus nerves; therefore, with a current at all strong, the current closing must be very short. We interrupt, then, the current immediately after its closing by removing pressure on the interrupting-handle.

* Besides, the faradic current has no appreciable effect on the conduction resistance, while the galvanic current reduces it (see page 14). Consequently we get more accurate results if we apply the induction current first.

We avoid, however, removing the exciting electrode from the excitable point once we have found it. Current closing and opening are provided only by means of the interrupter. The electrode should remain at this point until the conclusion of the entire examination; even moving it a millimeter or the slight raising of one edge of the electrode often alters the result considerably. In longer investigations it is well to indicate the most excitable point, when once we have found it, with a dermatographic pencil.

Exciting Electrode to Remain Stationary

In difficult investigations it may be helpful if an assistant attends to the placing and moving of the apparatus or notes the result of the investigation. Generally, however, one can very conveniently get along alone. Only it is advisable for the beginner to conduct the investigation jointly with another, because thus the abovementioned retention of the most excitable point is better accomplished, and because, moreover, two persons can assist each other in determining clearly the quality and quantity of the muscle contraction. For the finding of the most excitable point, the seeing of the minimal contraction, and the recognizing of the contraction form (whether lightning-like or not) are the principal, almost the only difficulties of practical electro-diagnosis. Do not press the electrode with unnecessary force upon the underlying parts, for if it is well moistened—either with warm or salt water—the pressure is usually superfluous. Only at certain very deep-lying points, *e.g.*, with the facial nerve or with the radial nerve in the upper arm, is a certain pressure necessary; especially at the latter

Difficulties

point the electrode is liable to be thrown off through the contraction of the triceps muscle.

Determination of Most Excitable Point

If we have actually seen the proper contraction in the place where, according to experience, the nerve or muscle is most easily excited, then testing, as it were, along the course of the muscle, we apply the electrode open in several places and make one or two closures at each place, thus examining the entire neighborhood of the point first found, to see if we can not perhaps get a stronger contraction with the same current intensity. If that is not the case, then the point first found is the most excitable. (We shall further discuss this later.)

In the following, the most excitable points of the nerve and the most important muscles of the body will be treated separately and in the following manner: (1) The place will be described at which these points mostly lie. Moreover, these places are indicated and projected on the skin in schematic figures; under each schematic figure—drawn on transparent paper—is found a plate corresponding with it in outline, which is intended to call to mind the anatomical course of the muscles and nerves in question.* It will be easy to observe the position of the most excitable points by comparison of both plates, but a study of the course of the muscle will especially assist the understanding of its function, which is much more important. Then there will be indicated (2) the principal function which each muscle performs, what

*These drawings are made by Mr. Arthur Levin, according to my own instructions (the underlying plates are adapted from Quain and Hoffman's muscle pictures).

muscles are supplied by each nerve, and what effect consequently follows from its stimulation. Why it is necessary to know this has been explained above (page 52).

Nerves and Muscles of the Face.

(See Fig. 17 on the plate.)

Nerves and Muscles of the Face.

In all investigations of the face, we hold one hand against the side of the patient's face not being examined, in order to avoid movement. In examining the muscles around the mouth, have the mouth opened slightly.

The trunk of the *facial* nerve can usually be stimulated at two places:

Facial Nerve

1. In the angle between the mastoid process and the descending ramus of the lower jaw. We press the electrode upward as much as possible, and, as if we wished to touch the stylomastoid foramen itself, forward, into the angle, pushing it beneath the ear lobe. The effect is contraction of all the muscles of the face supplied by the facial nerve. The muscles of the top branch (the frontal and the corrugator supercilii muscles) often contract only weakly or not at all in this process. The nerve is moderately excitable.

2. At the tragus of the ear. There we also get often only an effect of the second and third branches. This point is not constant.

We can stimulate separately the three branches of the facial. The most excitable points usually lie about in a perpendicular line under each other; the middle one on the *tuber ossis zygomatici* or a little underneath; the

upper one just over the point where the imagined perpendicular line cuts the superciliary arc; the lowest just under the point where the imagined line strikes the lower border of the horizontal ramus of the lower jaw.

In stimulating the upper branch, the frontal muscle and the corrugator supercilii contract; we see wrinkling of the forehead and the eyebrow.

In stimulating the middle branch, contractions occur in the orbicularis oculi muscle, the zygomatici, the muscles of the nose, the raiser of the upper lip, the orbicularis oris muscle (often also only the upper half). Effect: closing of the eye, laughing, turning up of the nose, and wrinkling of the upper lip (pouting).

In stimulating the lower branch, contraction occurs in the levator menti muscle, depressor labii inferioris muscle, and depressor anguli muscle (at times also the lower half of the orbicularis oris). Effect: lifting of the chin, turning over of the under lip, and drawing of the corner of the mouth downward and outward. The three branches are easily excitable, the first the most and the second the least.

Of single muscles that may be stimulated in the face there are to be mentioned:

Frontalis Muscle

The *frontalis* muscle, excitable mostly near the outer and upper corner of the respective half of the forehead near the border of the hair. Effect: transverse wrinkling of the forehead and raising the brow. The faradic stimulation here is painful, so let the current closure be short. With the galvanic stimulation there (as also in

case of the other facial muscles) dizziness, flashes of light, etc., are easily produced.

Muscles of the Orbital Region

The *corrugator supercilii* muscles, mostly a little in from the nerve point of the upper branch. Effect: wrinkling up and down of the region between the eyebrows. We distinguish this point from the neighboring nerve point by the fact that with the latter also a frontal effect is seen; that nerve point is also more excitable.

The *orbicularis oculi* muscle in the outer angle of the orbit. Effect: movement of both lids toward each other. In pathological cases (reaction of degeneration) the most excitable point of this muscle is often found on the under or upper lid.

Nasal Region

The *nasal* muscles, difficult—and in general unnecessary—to isolate, excitable toward the median line, from the inner corner of the eye in the vicinity of the root of the nose. Effect: nasal rumpling and slight lifting of the upper lip.

The *zygomatic* muscles, a little to the side and under the former point. Effect: laughing.

Maxillary Region

The *orbicularis oris* muscle, excitable in two halves: (*a*) The upper portion, about half a finger breadth above the red of the lip, a little to the middle from the outer corner of the mouth. Effect: wrinkling and pointing of the upper lip. (*b*) The under portion near to the red of the lip and somewhat more toward the middle than the upper point. Effect: wrinkling and pointing of the under lip.

The *mentalis* muscles, or levator menti, on the chin near the border of the lower jaw bone and right close to

the median line. Effect: chin lifting and wrinkling. The beginner is liable at this point to stimulate at the same time the symmetrical muscle of the other side.

The *depressor labii inferioris* muscle or quadratus menti, a little to the side and above the former point. Effect: turning over of the lower lip to the outside. This is often difficult to separate from the former or from the following muscle.

The *depressor anguli oris* muscle, or *triangularis menti* almost directly at the lower border of the horizontal ramus of the lower jaw, a little to the outside and below the former. Effect: pulling downward and outward of the under lip. This muscle lies in the vicinity of the nerve point for the third facial branch. The effect of the latter we can usually distinguish from that of the muscle, without mentioning that the nerve is usually more excitable, because by stimulation of the nerve branch the mentalis muscle also contracts, causing elevation and wrinkling of the chin. In pathological cases we often find the point of this muscle far above toward the lip.

In the face we find also two more muscles, that are supplied, not by the facial, but by the third branch of the trigeminus, namely:

Temporo-Maxillary Region

The *masseter* muscle, about in the middle between the cheek-bone arch and the horizontal ramus of the lower jaw, considerably far to the side, about one and one-half or two fingers' breadth inward from the lobe of the ear; and the *temporal* muscle, about in the middle of the temporal groove, about equal distance from the upper

border of the cheek-bone arch and from the border of the hair, or nearer the first. These last two muscles effect mastication—they bring the teeth together. Both are mostly excited only with strong currents. In paralysis of the facial nerve, with loss of its excitability, one often sees movements of both these muscles distinctly produced after stimulation at the point of the facial. Let the beginner guard against confounding this movement then with facial contraction.

Levator Palpebræ Superioris Muscle

In pathological cases of peripheral oculomotor paralysis, we can, with the galvanic current, cause the levator palpebræ superioris muscle to contract, the only eye muscle excitable under the circumstances, by means of a button-formed electrode, several millimeters under the highest point of the supraorbital arch (Werthheim and Salomonson).*

NERVES AND MUSCLES OF THE NECK.

(See Fig. 17 on the plate.)

Nerves and Muscles of the Neck

Because of the very different configuration of the region of the neck, and especially of the location of the most excitable fossa supraclavicularis, the most excitable points will differ greatly in different persons. In many cases we shall have to be satisfied with the discovery of the most important nerve points. The more expert we become, the oftener shall we have positive results. We

* Its contraction form, let it be said right here, is "sluggish," and its electrical excitability is, moreover, a positive sign of increased excitability due to disease. (These symptoms of disease will be further described in Chapter IV., "Reaction of Degeneration.")

use for the neck an exciting electrode of only very small diameter (button electrode). These small electrodes must be thoroughly moistened.

Spinal Accessory and Hypoglossus Nerves

The *accessory* nerve, in the posterior triangle of the neck, about two fingers' breadth under the upper angle, near the upper portion of the cucullaris muscle. This nerve is very easily stimulated. Effect: contraction of the sterno-cleido-mastoid and the cucullaris muscle (which also receives filaments from the cervical plexus), head inclination toward the back, the patient lifts and turns the chin toward the other side.

The *hypoglossus* nerve is usually excitable immediately above the hyoid bone.

Brachial Nerves

The *brachial* plexus in the entire lower inner third of the fossa supra-clavicularis and parts of it are easily reached laterally from it. Effect: changing with the point of stimulation, mostly in the median and axillary region, bending of the hand and the fingers, abduction of the arm from the thorax, and forcible bending of the elbow in a pronated position. This is regularly to be found and as a rule is easily excitable.

Erb's Point

Erb's (supra-clavicular) *point*—a point in the cervico-brachial plexus—generally a little more than a thumb's breadth above the upper clavicular border and a little to the side of the sterno-cleido-mastoid. It naturally changes its position considerably, according to the form of the upper clavicular hollow. From this point out we get contraction of the deltoid, biceps, brachialis internus, and brachio-radialis muscles; that is, a jerking abduction of the arm from the thorax and forceful bending of the

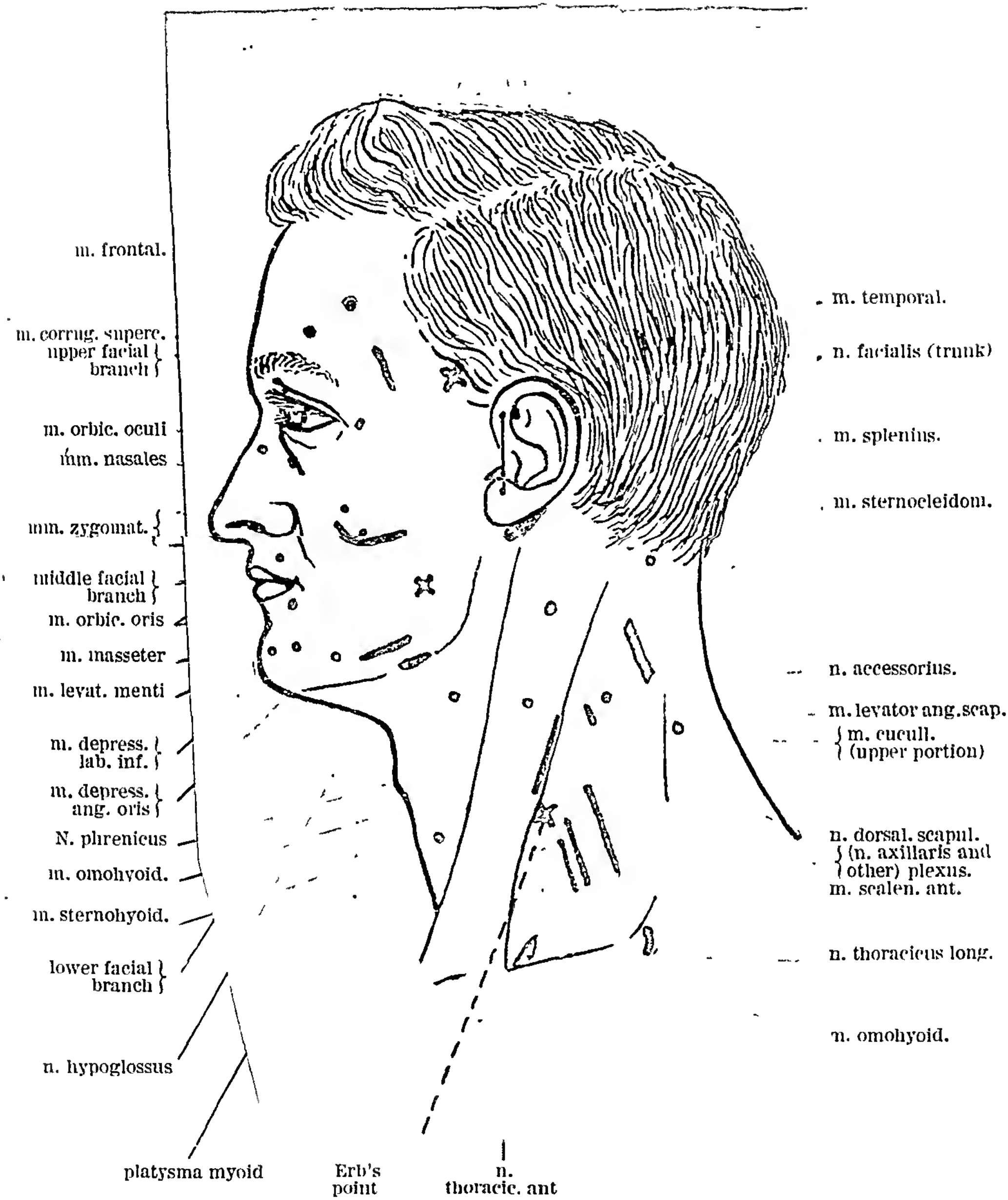

m. frontal.
m. corrug. superc.
upper facial branch
m. orbic. oculi
mm. nasales
mm. zygomat.
middle facial branch
m. orbic. oris
m. masseter
m. levat. menti
m. depress. lab. inf.
m. depress. ang. oris
N. phrenicus
m. omohyoid.
m. sternohyoid.
lower facial branch
n. hypoglossus
platysma myoid
Erb's point
n. thoracic. ant
m. temporal.
n. facialis (trunk)
m. splenius.
m. sternocleidom.
n. accessorius.
m. levator ang. scap.
m. cucull. (upper portion)
n. dorsal. scapul.
(n. axillaris and other) plexus.
m. scalen. ant.
n. thoracicus long.
n. omohyoid.

FIG. 17.

elbow in a pronated position. This is regularly to be found and as a rule is easily excitable.

The *anterior thoracic* nerves. We must press in the button electrode deeply, behind the clavicle, with the arm of the patient hanging down, and choose not too weak a current. Even then we must often abandon the search for the discovery of the point. Effect: contraction of the pectoral (adduction of the arm to the thorax). Thoracic Nerves

The *long thoracic* nerve. This nerve is often not excitable at the neck; if it is excitable, then it is in the outer corner of the posterior cervical triangle, with the button electrode pressed in deeply. Effect: contraction of the serratus anticus major muscle (the shoulder blade is moved outward and forward), or we see single points of the serratus come into prominence.

The *axillary* nerve. This nerve is a little to the middle and above the former, near the outer corner of the triangle. It is frequently isolated, even tho parts of the plexus are often stimulated with it (in many persons it may be stimulated in the armpit, and often together with the radial nerve). Effect: deltoid contraction (abduction of the arm from the thorax). Axillary Nerve

The *dorsalis scapulæ* nerve. This nerve is often excitable, but not very easily, a little to the inside from the above. Effect: contraction of the rhomboid and the levator scapulæ. Lifting of the shoulder-blade with turning upward and inward. Dorsalis Nerve

The *phrenic* nerve. It is seldom sought for diagnostic purposes; for therapeutic purposes (asphyxia) it is generally isolated from either side, either by fastening a fork Phrenic Nerve

5

attachment to the conducting-cords of the exciting-electrode and attaching to its ends two small exciting-electrodes of equal diameter (3 sq. cm. or less), or by doing away with the indifferent electrode and choosing two small button electrodes, one provided with an interrupter, which we place one on each side of the neck. The most excitable point is often behind the sterno-cleido-mastoid, sometimes at the end of its upper third, at other times farther down. We must therefore push the electrode in back of the muscle, as if we were trying to lift the muscle up. If the point is not rightly reached, the electrode will often be thrown out by the contraction of the sterno-cleido-mastoid, or, instead of the effect sought, plexus contractions or the like may occur. Effect: diaphragm contraction (arching of the epigastrium, particularly rushing of the air into the air-passages with audible sobbing sound).

There are to be mentioned of the muscles of the neck:

Muscles of the Neck

The *sterno-cleido-mastoid* muscle, most easily excitable somewhere in the middle. Effect: projection of the muscle from the contour of the neck, turning of the head toward the other side, the auricle being inclined forward.

The *omo-hyoid* muscle; its stimulation is practically without importance (see Fig. 17). Effect: prominence of its outline in extension.

The *levator anguli scapulæ* muscle, often excitable directly under the axillary point. Effect: raising of the shoulder with slight turning of the head toward the stimulated side.

The *splenius* muscle of the head and neck, directly under the mastoid process. Effect: it turns the head toward the stimulated side.

The *platysma myoides* muscle, in the anterior triangle of the neck, pretty high up, somewhat below the level of the hyoid bone. Effect: tension of the skin of the neck and slight drawing down of the corner of the mouth. For its stimulation apply the electrode very lightly on the skin, without using the least pressure.

Laryngeal Stimulation

The larynx and likewise the palatal and the tongue muscles are not difficult to stimulate with electrodes of the proper size. It is worth noting that, in brushing the region at the side of the larynx from above downward with the Ka. of the galvanic current (of 15 sq. cm. diameter, with currents of medium strength, 3 to 6 ma.), swallowing movements can easily be produced. Faradic currents do not produce this effect.

Nerves and Muscles of the Upper Extremity.

(See Figs. 18 and 19 of the plate.)

Nerves and Muscles of the Upper Extremity

For the investigation of the muscles and nerves of the arm, we lay the patient's arm, slightly bent at the elbow, on a rest, preferably on our own disengaged hand. We should not grasp it, however, with the hand and prevent with our own thumb the effect of the muscle stimulation. We use our own hand (with not opposing thumb) only, as said, as a support. According as we have to deal with the right or the left half of the body, with the extensor or flexor side, we will hold naturally

the exciting-electrode either in the right or in the left hand.

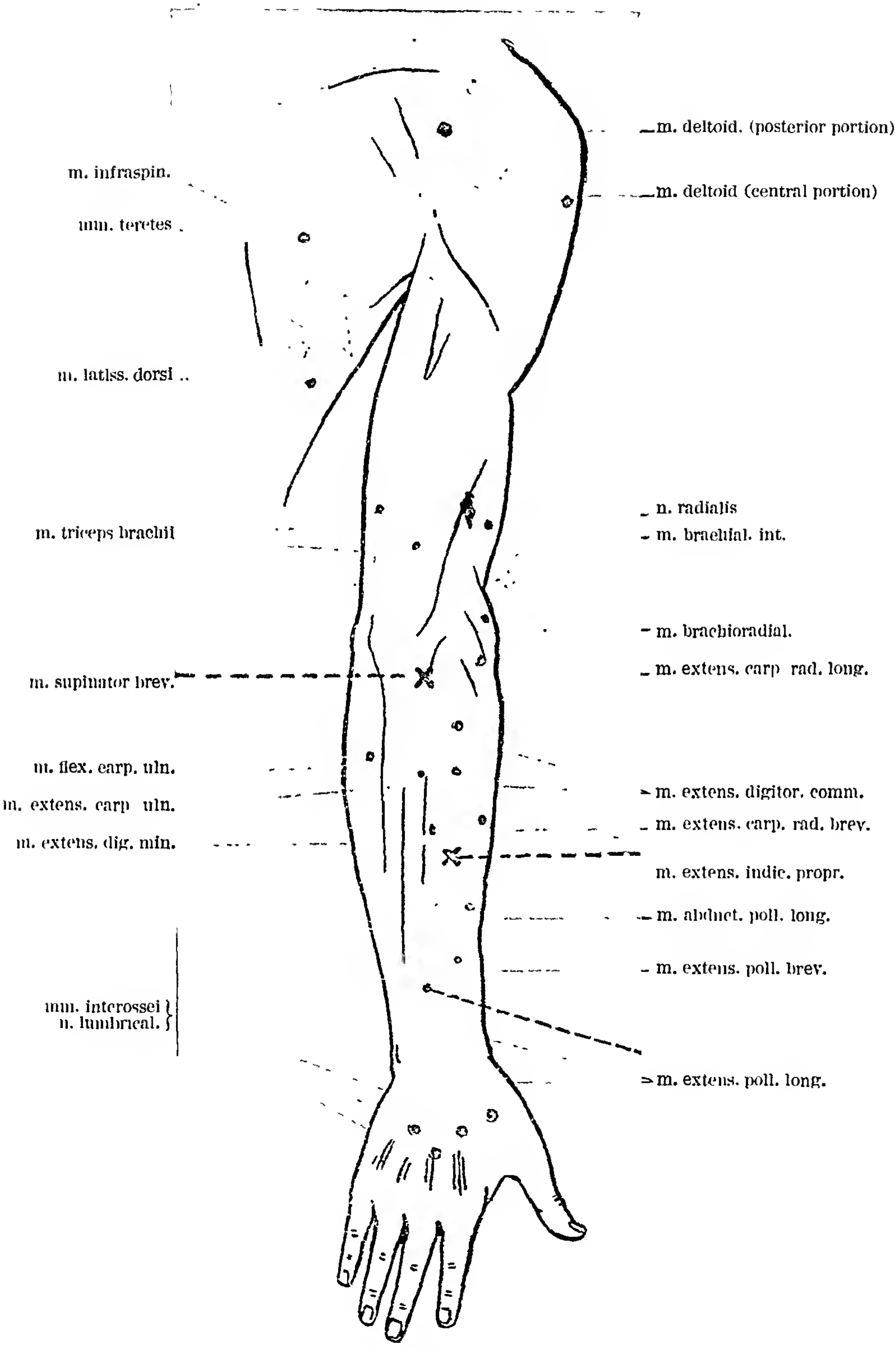
Radial Nerve

The *radial* nerve, at its winding-point at the outside of the upper arm, in the middle between the insertion of the deltoid muscle and the external condyle of the humerus. At this point or also somewhat above or below, with one hand, we apply the exciting electrode, pressing firmly downward on the front lateral edge of the triceps, at the same time supporting the arm, lifted and slightly bent at the elbow, with the other hand.

Sometimes in doing this we must direct the pressure of the electrode somewhat more toward the front, oftener somewhat more toward the back. It is best if one applies it directly above the point where one has found, through careful search, the uppermost point of the origin of the brachio-radialis on the humerus. If we use rather strong currents or move the electrode toward the front, contraction of the very easily excitable biceps occurs, which obscures all other effects.

Effects: contraction of the extensor muscles of the hand and fingers (supinator brevis and the brachioradialis, not quite regularly); therefore extension of the hand and fingers, as also supination and bending of the elbow. It is to be noted: (1) That the radial nerve is usually much more easily excited by the Ka. of the galvanic current as well as by the Ka. of the faradic current (opening) than by the An., and it is stimulated on the whole with greater difficulty by the faradic than by the galvanic. (2) With the faradic current, particularly with rather strong currents, the contraction in the radial region does not continue during the entire duration of the

PLATE II.


m. deltoid. (posterior portion)
m. infraspin.
m. deltoid (central portion)
mm. teretes
m. latiss. dorsi
n. radialis
m. triceps brachii
m. brachial. int.
m. brachioradial.
m. extens. carp rad. long.
m. supinator brev.
m. flex. carp. uln.
m. extens. digitor. comm.
m. extens. carp uln.
m. extens. carp. rad. brev.
m. extens. dig. min.
m. extens. indic. propr.
m. abduct. poll. long.
m. extens. poll. brev.
mm. interossei
u. lumbrical.
m. extens. poll. long.

current closing, but is mostly only transiently appreciable. This results from the fact that the most excitable point of the nerve is near the most excitable point of the triceps, and that the electrode is pushed out of the hollow by the contraction of the triceps, and thereby is removed from the nerve. Particularly in stimulating this nerve point, an important matter in practise, we should be careful not to cover up with our own hand the effect of the electrical stimulation, an error into which beginners very often fall.*

The *ulnar* nerve. (1) In the ulnar fossa inside from the olecranon. In stimulating this nerve, let the arm of the patient remain raised at the shoulder with the elbow half bent, the hand, with the palm down, hanging loosely. Effect: contraction of the interossei muscles, the adductor pollicis muscle, the flexor carpi ulnaris muscle, and one part of the deep finger flexors. We see, therefore, a bending of the hand toward the ulna, an entire bending of the two or three last fingers (the bending of the second and third phalanx of the middle finger is generally not complete), an adduction of the index finger to the middle finger and of the thumb to the index finger; at the same time the thumb is extended, as are generally the last two phalanges of the index finger. The position with ulnar stimulation which is most typical is especially to be recognized by the behavior of the thumb and the index finger, and can be differentiated from other effects of stimulation. Also at the upper arm, in the upper part Ulnar Nerve

*The radial may also be stimulated way up in the rear part of the armpit, but can not usually be separated from the axillary.

in the sulcus bicipitalis internus, in the lower part more toward the middle from it, the nerve can be strongly and easily excited.

(2) The lower part of the nerve may be stimulated directly over the wrist on the ulnar side. When we press in the electrode over the carpal bones, then we get only the adductor pollicis and the interosseus effects, adduction of all the fingers to each other, flexion of their first and extension of their last phalanges.

Musculo-Cutaneous Nerve

The *musculo-cutaneous* nerve. At the upper part of the upper arm where the lower border of the pectoralis major muscle crosses the sulcus bicipitalis internus; there the nerve trunk itself may incidentally be stimulated, much more easily than the intramuscular biceps which is supplied by this nerve-trunk (the nerve also supplies the brachialis internus).

Median Nerve

The *median* nerve. We stimulate it most frequently: (1) In the middle of the elbow-joint, directly on the outside from the lacertus fibrosus. Also we can stimulate it in the whole sulcus bicipitalis internus; there, however, its effect is often mixed (namely, there are ulnar and musculo-cutaneous effects with it). The stimulation effect consists of a contraction of all the hand and finger flexors, of the pronators, and of the muscles of the ball of the thumb; forcible flexion of hand and fingers beginning with a jerk; complete pronation of the forearm and apposition of the thumb. Apply the electrode with light pressure, and hold the arm of the patient bent at the elbow, with the palm turned up. The very strong pronation which occurs when the

nerve point is reached often leaves the contractions of the thumb-ball muscles unrecognized; we may appreciate this, however, when we hinder pronation by resistance.

(2) The median nerve may be excited in several places in its course, in the middle of the forearm, flexor side, best directly over the middle of the wrist between the two tendons of the flexor carpi radialis muscle and the palmaris longus muscle, which are prominent there, or also at the ulnar border of the tendon of the last. Effect: apposition of the thumb (contraction of the lumbricales).

Muscles of the Hand, Palmar Surface

The muscles of the ball of the thumb, particularly the opponens muscle and the outer portion of the flexor brevis pollicis and abductor pollicis brevis on the ball near the wrist, are easily excitable when the hand is held in a relaxed position. Effect: apposition of the thumb and bending of the thumb metacarpal bone.

The *abductor pollicis brevis* muscle is excitable near the radial border of the ball of the thumb, proximal, that is, nearer the wrist than the metacarpo-phalangeal joint; it may also be isolated.

The adductor pollicis muscle either is in common excitable with the first interosseus (see below) or also often in the palm toward the ulna from the ball of the thumb, somewhat over the middle metacarpal of the index finger. Both these muscles, in common with the inner portion of the flexor brevis, cause flexion of the first, extension of the second phalanx of the thumb, and respectively abduction and adduction.

The *interossei* muscles and *lumbricales* are jointly tried;

they are very important muscles. The most excitable points lie on the dorsal side of the hand rather far proximal (toward the shoulder) in the interosseal spaces. We must at times exert some pressure on the electrode in order to excite them, and must exercise care that they are relaxed. Let the hand which is being examined hang, with the palm down, over a rest, or let the physician support it lightly with his own hand at the carpus; or allow it to rest with the palm on his own fingers, while the fingers of the patient hang loose, preferably loosely separated from each other. Stimulation in every interosseal space causes: (1) approximation of both fingers between which it lies; (2) flexion of their first phalanx and extension of the last two phalanges.*

Current Streamer Effects

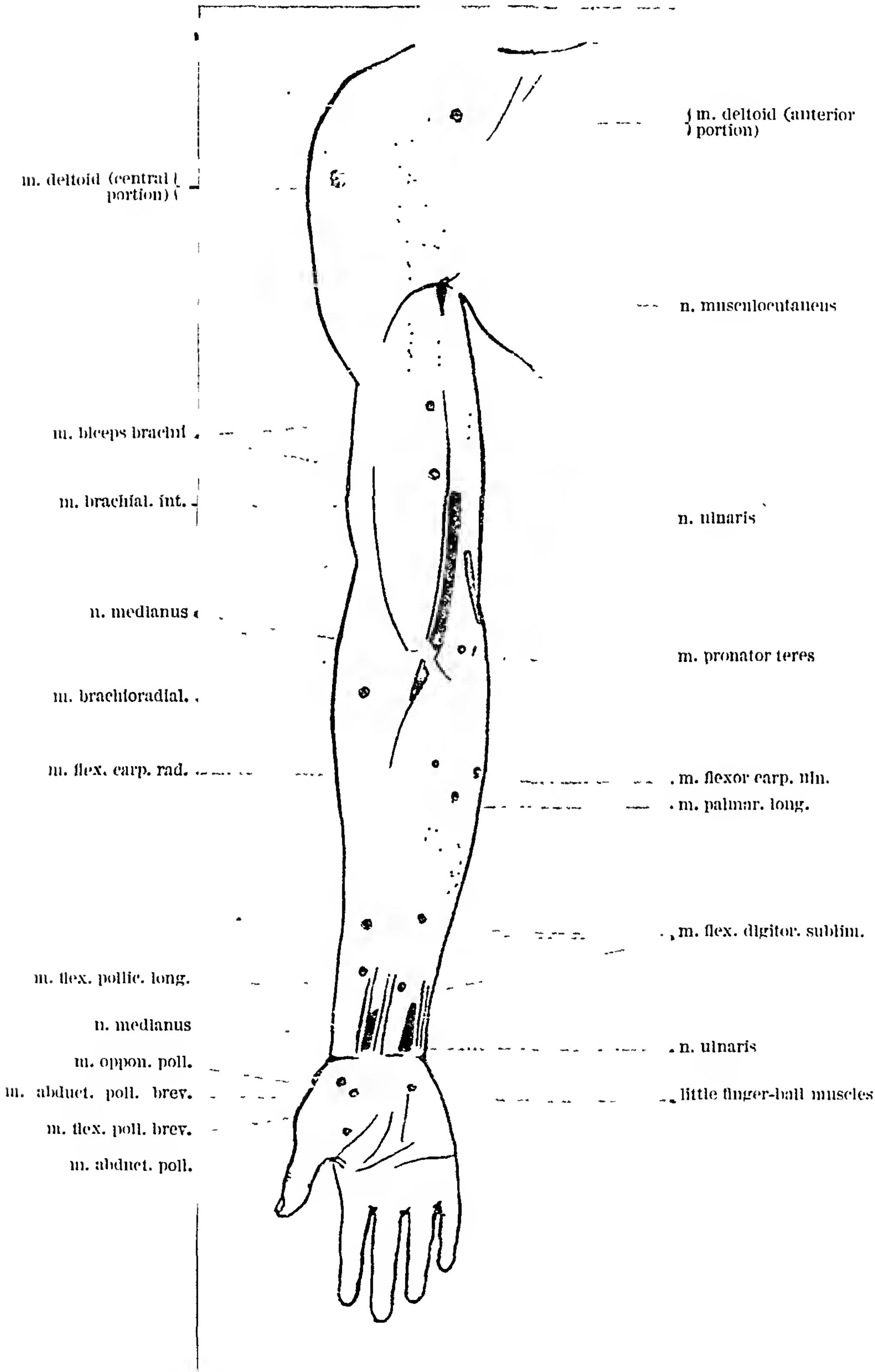
In the application of strong currents (which, *e.g.*, is necessary in atrophic conditions in order to exclude extinction of excitability) current streamers easily produce on the long finger flexors or extensors a seeming interosseal effect. Let the beginner be on the lookout for this, and always observe whether the first phalanx is actually flexed and the last two are extended.

The muscles of the ball of the small finger (the opponens, flexor, abductor digiti minimi muscles) are excited at the root of the hypothenar. They produce the effects expressed by their names, and are not always to be isolated.

To test the muscles on the extensor side of the fore-

*Since in paralysis of the interossei (ulnar paralysis) the antagonists overbalance, overextension of the first and flexion of the last phalanges occur (claw-hand).

PLATE III.


m. deltoid (anterior portion)
m. deltoid (central portion)
n. musculocutaneus
m. biceps brachii
m. brachial. int.
n. ulnaris
n. medianus
m. pronator teres
m. brachioradial.
m. flex. carp. rad.
m. flexor carp. uln.
m. palmar. long.
m. flex. digitor. sublim.
m. flex. pollic. long.
n. medianus
n. ulnaris
m. oppon. poll.
m. abduct. poll. brev.
little finger-ball muscles
m. flex. poll. brev.
m. abduct. poll.

arm, bend the elbow of the patient and place the hand itself in slight pronation. We then excite:

Muscles of the Brachio-Radial Region

The *brachio-radialis* muscle (the supinator longus), where the radial crosses from the extensor to the flexor side of the antibrachium. If we direct the patient to bend the elbow midway between pronation and supination, and resist this bending, at once we see, near the point where the muscular bulge is most prominent, this muscle spring into bold relief. The effect of the electrical excitation is flexion of the elbow-joint and slight pronation of the hand (the name supinator longus is a misnomer). In order to see the pronation better, give the hand of the patient a slightly supinated position.

The *supinator brevis* muscle, toward the ulnar side from the former, about at the external condyle of the humerus or somewhat distal from it. It causes sharp supination. One can frequently observe in the case of this muscle, which is often excited with difficulty, that with many persons it reacts only to one of the two faradic poles (sometimes to the An., sometimes to the Ka.), whereas by the application of the other pole at the same point we excite another muscle, *e.g.*, one of the wrist extensors.

Between the two last-named muscles, nearer the most excitable point of the brachio-radialis, lies the point of the *extensor carpi radialis longus* muscle very far proximal, on the forearm; it extends the wrist and at the same time moves it toward the radius.

Its opposite on the ulnar border is the *extensor carpi ulnaris* muscle rather near the ulnar edge, about three

fingers' breadth from the olecranon; it likewise extends the wrist, but moves it toward the ulna.

Muscles of the Hand, Dorsal Surface

The point of the third wrist extensor, that one which extends the wrist nearly straight upward, the *extensor carpi radialis brevis* muscle, lies between the last two, near that of the radial extensor, and about four fingers' breadth distant from it. It can not always be easily excited separately from the extensor digitorum communis muscle.

The *extensor digitorum communis* muscle, about a hand's breadth below the elbow-joint, at the end of the upper third of the forearm, extends the first phalanges of the fingers and causes an extension effect on the wrist. Portions of it, extending to the separate fingers, can often be stimulated individually. In its degeneration, *e.g.*, in lead paralysis or radial relaxing palsy, the finger flexors are usually excited from this point by current streamers. In lead paralysis and similar conditions it also often happens that only some parts of it show a pathological reaction, namely, become entirely unexcitable (mostly those in the middle), while the rest remain intact. Particularly to be mentioned is:

The *extensor indicis proprius* (or indicator muscle), not connected with the former and generally lying covered; generally excitable somewhat toward the radius from the middle of the forearm, extensor side (it extends the index finger forcibly); and the

Extensor digiti minimi proprius muscle, toward the outside of it; it extends the small finger and abducts it a little.

The *extensor pollicis longus* and *brevis* (the thumb extensors) and the *abductor pollicis longus* are excitable near the radial border of the extensor side, about four fingers' breadth above the wrist (here mostly the abductor alone), then somewhat toward the ulna and somewhat toward the elbow from the point named. These muscles (of which the abductor longus and the extensor brevis border the so-called "snuff-box" muscle on the radial side, the extensor longus on the ulnar side) move the thumb in the following manner:

The extensor pollicis longus extends the thumb and the first metacarpal bone and draws it toward the second.

The extensor brevis abducts the first metacarpal and extends the first phalanx of the thumb (with second flexed).

The abductor longus (the thumb phalanges are slightly flexed) moves the first metacarpal toward the front and outward. They are often difficult to isolate.

On the flexor side of the forearm we excite the muscles, placing the arm, bent at the elbow, in half supination. Farthest ulnarward lie the group of hand flexors and pronators arising from the internal condyle and near it.

Muscles of the Anterior Brachial Region

The *flexor carpi ulnaris* muscle, farther toward the ulna, just at the border of the flexor and extensor sides, about a hand's breadth or little more distant from the elbow-joint. It bends the hand toward the ulna and does not pronate.

Radial and mostly somewhat distal from it, the *palmaris longus* muscle flexes the hand weakly, almost

straight upward. Its tendon, when we have it isolated, stands out sharply among the flexors of the hand. Often is it difficult to separate it from the

Flexor carpi radialis muscle, whose point lies a little more radial or elbowward. It flexes the wrist and the radial side more than the ulnar; also at the same time it pronates. Its tendon likewise stands out among the flexors of the hand and toward the radius from that of the palmaris longus. Between these two tendons there is often only a very narrow space.

Together with these three wrist-joint flexors, to which three wrist-joint extensors of the extensor side correspond, and most radial, lies the most excitable point of the

Pronator teres muscle, almost in the middle between the radial and ulnar borders of the flexor side, but usually nearer the ulnar border, and only two or three fingers' breadth below the elbow-joint. The position of this point differs very often in different persons. This muscle pronates sharply and as far as possible without moving the wrist or the fingers. Thus we can distinguish its effect particularly from that of the median nerve, which is often situated near it, and from which, moreover, an excitation of the muscles of the ball of the thumb usually follows.

Besides these muscles, which it is often not easy for the beginner to isolate and to recognize in their action, there are to be noted on the flexor side of the forearm:

The *flexor pollicis longus* muscles, in the lower third

of this side, very near to the radial border. These cause flexion of the end phalanx of the thumb.

The *flexores digitorum* muscles, *sublimis* and *profundus*, of which the former flexes the second, the latter the third phalanges of the fingers, may be found distributed at several points in the middle and lower third of the forearm, particularly the sublimis. We frequently find the flexors of the index finger, especially if we apply the electrode with some pressure, between the tendons of the pronator teres and the flexor carpi radialis, which stand out at the wrist about two fingers' breadth above the joint.

Muscles of the Anterior Humeral Region

In the upper arm we excite the *biceps* muscle with the elbow slightly bent and passive, the hand slightly pronated. Its most excitable point generally lies where the muscle bulge is most prominent, or inward and up from it. It is a very excitable muscle, and its effect is a forcible flexion of the elbow and an evident supination of the forearm. Therefore it is partly a helper, partly an opponent of the brachio-radialis, which flexes the elbow and pronates the forearm.

The third elbow flexor, the *brachialis internus* muscle, which flexes the elbow straight upward, under normal conditions can not be isolated at the inner side of the biceps, because either this or the nerve-trunks in the sulcus bicipitalis internus will respond to the stimulation. Its point lies under (behind) the biceps, on the inside, about in the lower third of the upper arm. But if we lift the biceps high and push the electrode under we can at times stimulate it oftener. It is excitable at the point

designated in Fig. 18, out from the biceps; between this the triceps and the upper border of the brachio-radialis. Under this excitation weak flexion occurs.

Muscles of the Posterior Humeral Region

To these three elbow flexors there corresponds a tripartite elbow extensor, the *triceps*-muscle. The common point for its three heads lies about a hand's breadth above the olecranon—that is, about on the boundary between its lower and middle third. The three heads, caput longum, caput internum, and caput externum, can also be excited separately farther up. We see the triceps action best when the elbow is in half passive extension.

The *deltoid* muscle is also excited in three portions: (1) The front portion, not far below the acromion, near the inner border of the muscle bulge, which portion is easily stimulated and lifts the humerus toward the front; (2) the middle portion at the side of the former, perpendicularly over the point of its insertion, about in the middle of the muscle bulge, which portion lifts the humerus rather forcibly toward the side; (3) the rear portion, behind the former, but, on the other hand, somewhat farther up, which portion lifts the humerus weakly backward. The last two portions are much less excitable than the first.

Muscles of the Trunk.

(See Fig. 20 on the Plate.)

Muscles of the Trunk

The muscles of the trunk are, with few exceptions, difficult to excite. We need strong faradic currents in order to see distant effects; but as several of them, *e.g.*,

the shoulder-blade muscles, have great practical significance, it is worth the practitioner's while to take some pains in the search for these points.

Muscles of the Back

The first is the *cucullaris* or *trapezius* muscle. We can distinguish three portions of this muscle: (1) The upper portion, most easily excitable from the front at the upper border of the supraclavicular groove, above the point of the accessory, or from the rear at the topmost portion of the muscle. The effect is a forward inclination of the occiput toward the excited side, with a lifting of the chin toward the opposite side; there is only a very slight effect on the shoulder. This portion of the muscle belongs to the most easily excitable points of the body. (2) The middle portion, most easily excitable about on a level with the spine of the scapula—or even higher—about in the middle between the inner border of the shoulder-blade and the spinal column. The effect is a forcible lifting of the shoulder. (3) The lower portion, excitable several finger breadths below the former point. The effect is adduction of the shoulder-blade toward the spinal column. The second and third portions of the muscle can usually be stimulated with strong currents only.

The *latissimus dorsi* muscle (see Figs. 18 and 20) can be excited best (with the arm hanging loose) inward from the lower angle of the scapula at the point where the muscle bulge approaching the armpit reaches the side of the thoracic wall. It adducts the hanging humerus to the thorax and draws it backward.

The *supra-spinatus* muscle, near the outer angle of the

fossa supra-spinata, is excitable only when the cucullaris is atrophic.

The *infra-spinatus* muscle (see Fig. 18), unlike the supra-spinatus, in most persons may be excited about the middle of the fossa infra-spinata by a current of moderate strength. It is a forcible outward roller of the humerus, and thereby aids the supination action of the upper extremity. With the arm hanging loosely and the forearm slightly flexed and supported we can demonstrate nicely the effect of electrical stimulation.

The *rhomboidei* muscles are hard to reach by direct electrical stimulation when the cucullaris is intact (for indirect stimulation see page 65). They draw the scapula obliquely upward and inward to the spinal column, at the same time lifting the lower angle of the scapula.

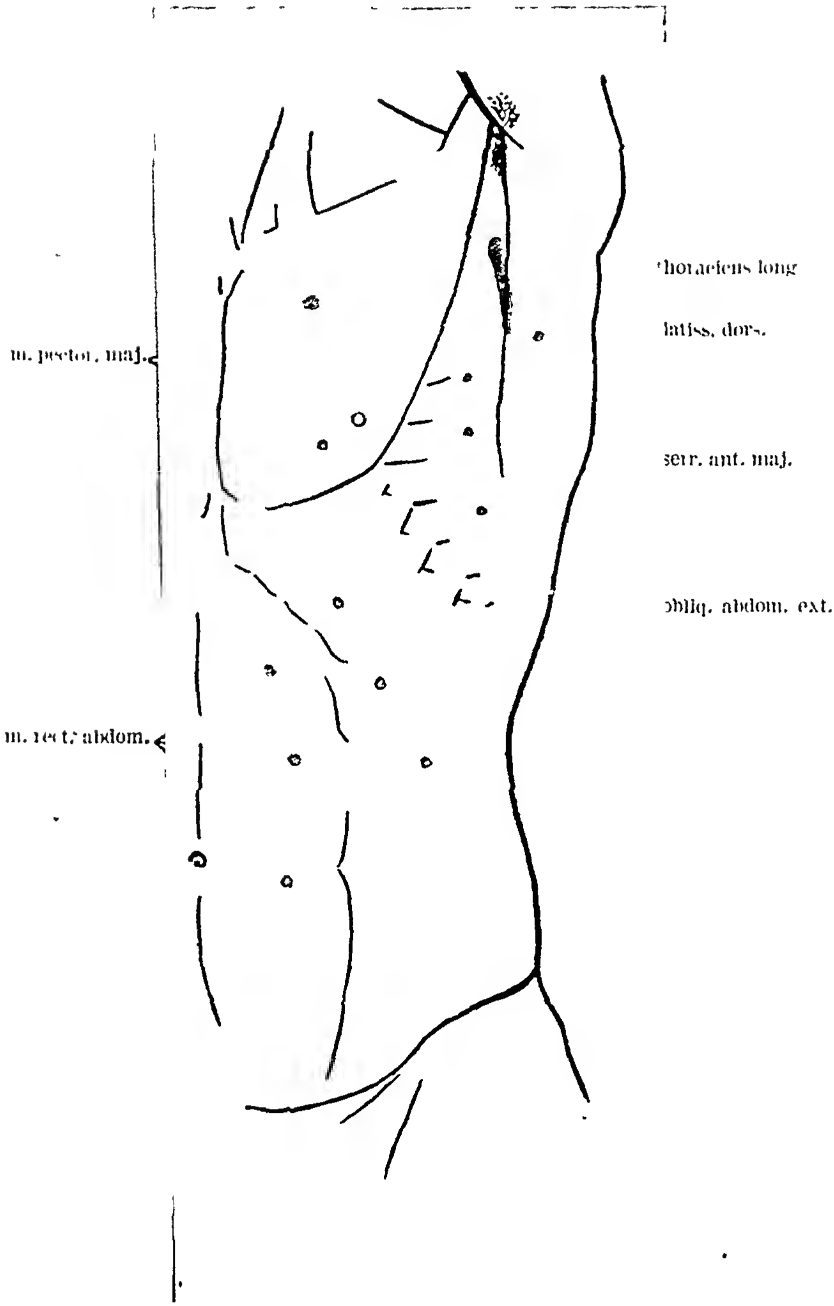
The *teretes* muscles can be reached incidentally by local stimulation (see Fig. 18). The *subscapularis* muscle is not excitable under normal conditions, nor, as a rule, is the *serratus posticus*.

The *erector trunci* muscles are often excitable with strong currents between the last ribs and the upper border of the pelvis. The effect is an inclination of the spinal column toward the excited side.

Muscles of the Thorax

The *serratus anticus major* muscle is indirectly excitable from the supra-clavicular fossa, as has been mentioned above (page 65), but is often excitable in the armpit on a line corresponding to the course of the nerve and about bisecting the angle of the armpit. The effect is that the serrations spring into relief, and the scapula

PLATE IV.


thoracicus long
latiss. dors.
m. pector. maj.
serr. ant. maj.
obliq. abdom. ext.
m. rect. abdom.

presses upon the thorax, and is lifted spasmodically and moved outward and forward.

The *pectoralis major* muscle (for indirect stimulation from the anterior thoracic nerves see page 65) is directly excitable at several points on the front chest wall, nearer its origin (at the clavicle, at the sternum, and in the ribs) than at its insertion. The effect is an adduction of the humerus to the thorax.

The *intercostal* muscles are excitable at the upper borders of the intercostal spaces with an electrode of very small diameter. Their electrical stimulation is practically unimportant and difficult.

Muscles of the Abdomen

The *rectus abdominis* muscle is excitable at the outer border of its muscle belly—that is, about three or four fingers' breadth to the side of the median line. As a rule, a point not far from the place where the outer border of the muscle touches the arch of the ribs is particularly excitable. The effect of stimulation is the drawing in of the abdomen on the stimulated side.

The *obliquus abdominis externus* muscle, farther out from the last-named point on the arch of the ribs, is unimportant. The effect of its stimulation is the drawing of the navel toward the stimulated side.

The *ileo-psoas* muscle, because of its deep position, can not be reached by electrical stimulation.

Nerves and Muscles of the Lower Extremity.

(See Plates 21–24.)

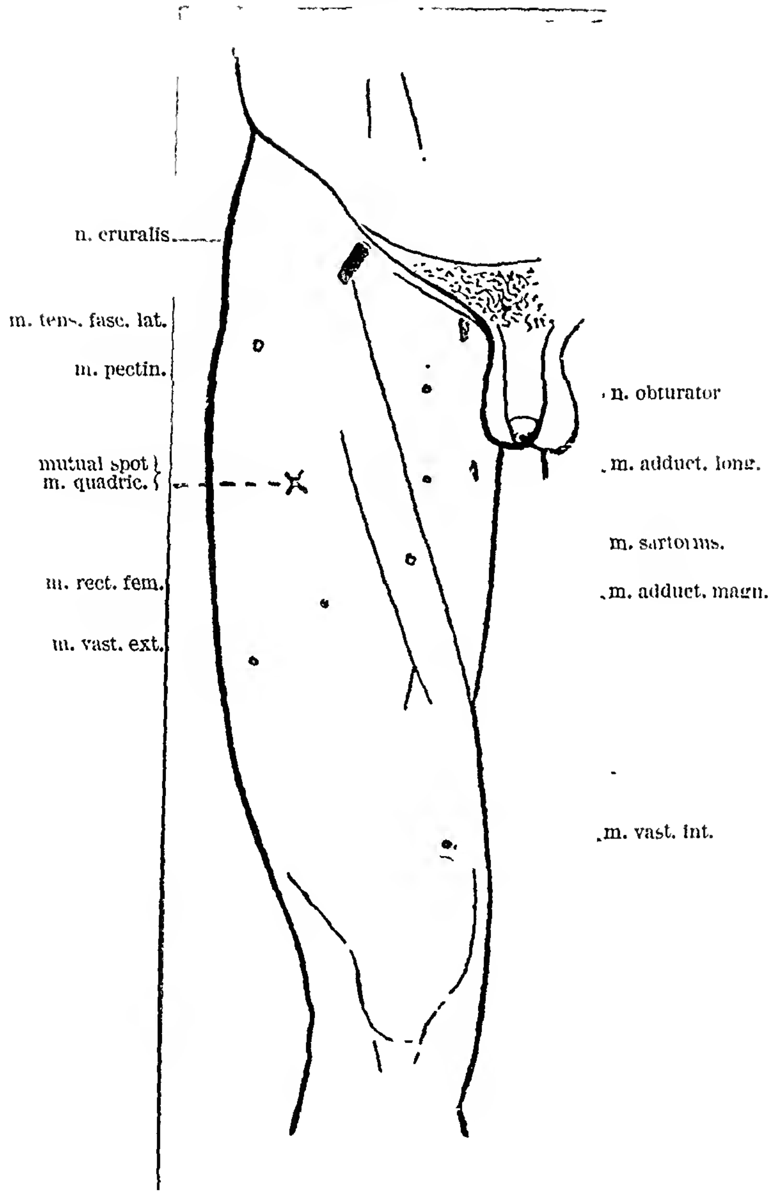
Nerves and Muscles of the Lower Extremity

In the lower extremity the search for the most excitable points is more difficult than in the upper, since frequently a much thicker layer (composed of skin, connective tissue, and in particular fat) is found between the electrode and the nerve or muscle, so that, with the inclination of the electric current to arc formation, a great part of the current is lost in the good conducting interposed tissue before a fraction reaches the muscle or the nerve. Therefore we frequently need, especially in the thigh, large current strengths to produce a visible effect. Several very deep-lying points can not be reached at all in many individuals. In regard to the position in which we place the leg to be examined, so as to have the muscles relaxed, see page 54. It is convenient to have among our apparatus a sofa, a divan, or some such similar arrangement, on which the patient can lie on the back during the examination of the front side of the leg, and on his stomach during examination of the back of the leg.

Crural Nerve

There are to be mentioned of the nerve points, the *crural* nerve, at the end of the inner third of Poupart's ligament, which lies very deep and is, therefore, often not excitable (or only with difficulty by considerable pressure of the electrode upward, outward, and backward). The effect is a contraction of the quadriceps

PLATE V.



n. cruralis
m. tens. fasc. lat.
m. pectin.
mutual spot
m. quadric.
m. rect. fem.
m. vast. ext.
n. obturator
m. adduct. long.
m. sartorius.
m. adduct. magn.
m. vast. int.

femoris muscle and the sartorius muscle, resulting in the forcible extension of the leg at the knee.

Obturator Nerve

The *obturator* nerve is often more difficult to excite than the preceding nerve. This is done by applying the electrode on the inside close to the symphysis, with considerable pressure and with strong currents. The effect is the contraction of the adductors.

Ischiadic Nerve

The *ischiadic* nerve, at the rear of the thigh, is usually reached only in thin persons and with strong currents and deep pressure of the electrode. If we draw an imaginary line from a finger breadth to the side of the tuber ossis ischii, between it and the trochanter major in the hollow of the knee-joint, the nerve will be found, if at all, at some point on this line (more frequently on its lower part). The effect is, flexion of the leg and dorsal or plantar flexion of the foot. Flexion of the leg alone might also be called forth by direct stimulation of the neighboring muscles.

Peroneal Nerve

The branches of the ischiadic are much more excitable than the trunk. We can excite very easily the *peroneal* nerve in the outer angle of the hollow of the knee by applying the electrode (the patient lying on the back and with slightly flexed knee) directly on the inner border of the tendon of the biceps femoris muscle and by pressing outward and under the tendon. We can also find this very excitable nerve point from there down to the little head of the fibula and even somewhat below it. The effect is the sudden dorsal flexion of the foot, in an almost straight direction, with the springing into relief of the muscle bellies and the sinews at the front and out-

side of the leg and the dorsum pedis (the peroneus longus and brevis muscles, the extensor digitorum communis longus and brevis, tibialis anticus, extensor hallucis longus muscle).

Tibial Nerve

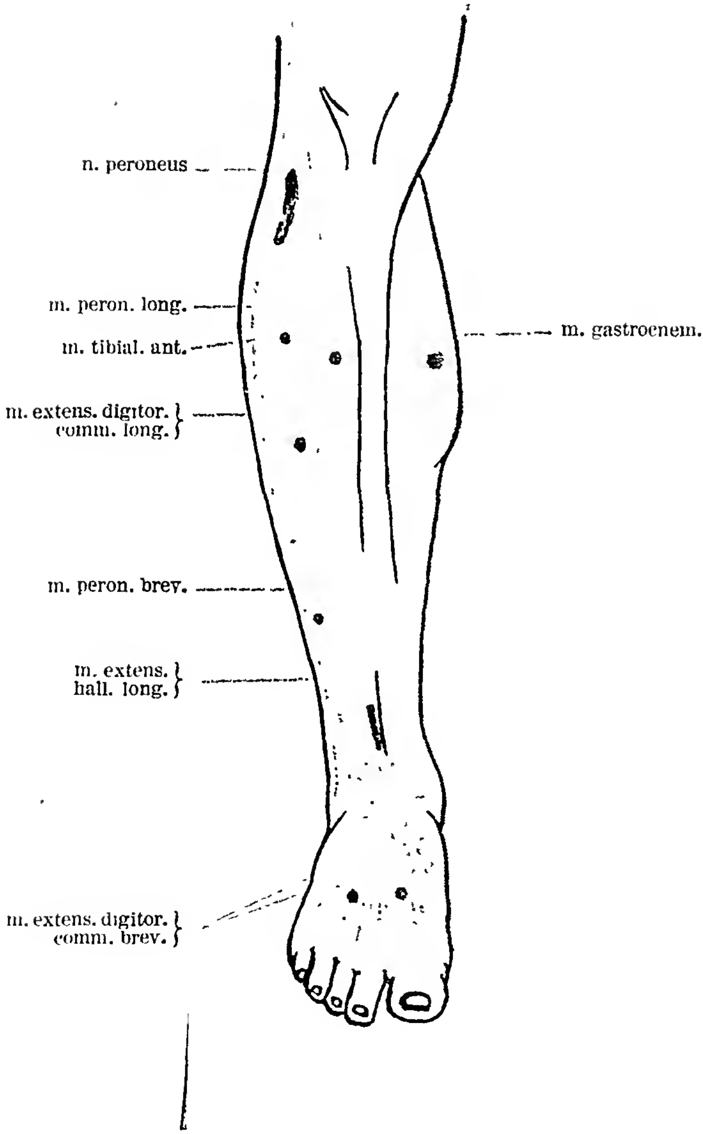
The *tibial* nerve, in the middle of the hollow of the knee or a little above it, can be easily stimulated, tho not so easily as the former. The effect is a contraction of the muscles at the rear side of the leg and the planta pedis, with forcible plantar flexion and flexion of the toes. Observe the toe-flexion or the wrinkling of the skin of the sole of the foot which usually accompanies stimulation of this nerve. If it is absent, we must determine whether the observed effect may not be traced back to stimulation of the muscle branch of the triceps suræ. A point at which we often obtain a single effect on the foot-sole muscles lies not far from the internal malleolus, toward the inside of the tendo Achillis.

The muscles of the lower extremity which are to be noticed are the following:

Muscles of the Anterior Femoral Region

On the front side: The *quadriceps femoris* muscle is affected by the joint excitation of its heads, generally above at the outer side at the thigh, about at the end of the upper third of the femur. The effect is an extension of the knee, and a moving of the patella almost directly upward. The excitability is good. There may be a separate excitation of the branch for the *vastus internus* muscle, about a hand breadth above the patella—that is, rather far distal, at the inner side of the muscle bulge. This is very easily excitable. The effect is a moving of the patella upward and inward.

PLATE VI.


n. peroneus
m. peron. long.
m. tibial. ant.
m. extens. digitor. comm. long.
m. peron. brev.
m. extens. hall. long.
m. extens. digitor. comm. brev.
m. gastrocnem.

The *vastus externus* muscle, at the outer side of the muscle bulge, but at a higher level than the former, is usually not so easily excited as the other. The effect is a moving of the patella upward and outward.

Also the *rectus femoris* muscle can be isolated a little below the common point.

The *sartorius* muscle can often be stimulated alone, about the upper third or in the middle of its muscle belly. With a certain current strength isolation is frustrated by simultaneous contraction of the quadriceps. The effect of the electrical stimulation is the springing into relief of the muscle belly. A locomotor effect is usually not produceable.

The *adductor* muscles, in the large adductor triangle bounded by the sartorius and the bend of the groin at different points, adduct forcibly. It is not easy, also not important, to isolate them (see Fig. 21, where the separate points are given).

The *tensor fasciæ latæ* muscle, at the outer border of the thigh, high up, not far beneath the crista ossis ilei, with a strong current produces a slight inward rotation of the leg from that point.

Muscles of the Tibio-Fibular Region

The *tibialis anticus* muscle, on the leg, on the outside close to the tibial edge, usually about two or three finger breadths below the knee-cap, on excitation produces the effect of lifting the inner border of the foot. Where there is not too great a layer of fat, we see the muscle belly and the tendon origin at the outer border of the tibia almost spring into relief. This is always easily excitable.

The *peroneus longus* muscle, about at the same level, but on the outer edge under the head of the fibula, is also quite regularly excitable. The effect is a sinking of the inner foot border and pushing down of the ball of the big toe. We plainly feel the latter, if during the electrical stimulation we press upward with our own hand the ball of the toe of the patient. Properly speaking, the muscle does not abduct.

The *peroneus brevis* muscle can often be isolated directly under the former, at the border of the middle and lower thirds of the leg, with a tolerably strong current. It causes a real but weak abduction of the foot.

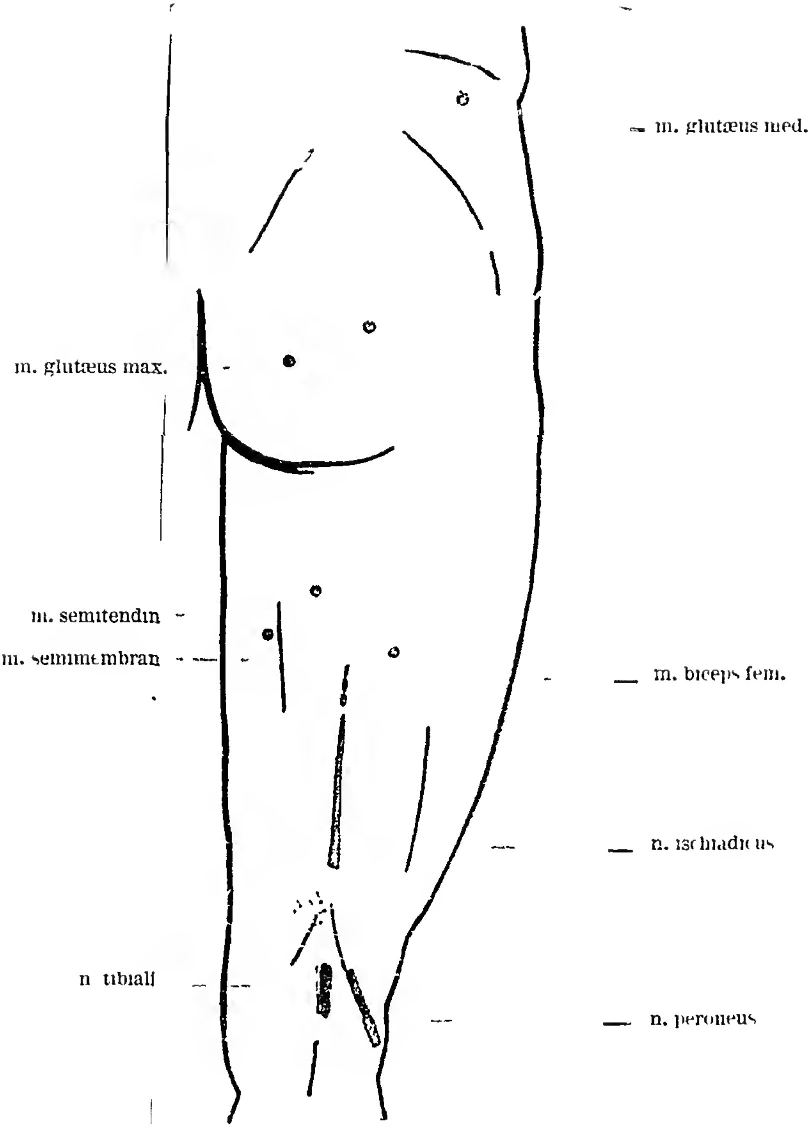
Muscles of the Plantar Region

The *extensor digitorum communis longus* muscle can not regularly be isolated between the tibialis anticus and peroneus longus; about in the middle, but farther distal, about a hand breadth below the patella, it causes a foot abduction and dorsal flexion, and extends the toe feebly; at the same time the affected tendon stands out at the back of the foot and over the ankle.

The *extensor hallucis longus* muscle, at different points above the ankle-joint on the inside, very near the outer edge of the tibia, likewise can not regularly be isolated. The effect is an extension of the first phalanx of the great toe.

The *extensor digitorum communis brevis* muscle, at the dorsum of the foot near the ankle-joint, rather far out from the middle line of the foot, when excited, forcibly extends the toes. With galvanic stimulation its contraction also is often not exactly lightning-like, even in the normal.

PLATE VII.


m. glutæus med.
m. glutæus max.
m. semitendin
m. semimembran
m. biceps fem.
n. ischiadicus
n tibiali
n. peroneus

The *abductor digiti minimi* muscle, which can be stimulated on the outside from the little toe, abducts this toe. This is unimportant, as is also the excitation of the *interossei* muscles (these latter as in the upper extremity).

Muscles of the Gluteal Region

At the back of the lower extremity is to be noted that the *gluteus maximus* muscle is rather easily excitablé at several points of its bulge, frequently most easily in the lowest part. The effect of the electrical stimulation is lifting and adduction of the buttock.

Here, too, it is to be noted that the *gluteus medius* muscle, somewhat above the prominent trochanter major, which lies below the crista ossis ilei, can be stimulated in some persons, but not always regularly, with strong currents, if the patient supports himself on both hands and on the leg that is not being examined, while the investigated leg hangs relaxed. If the stimulation is effectual, we see extension of the hip and abduction of the leg.

Muscles of the Posterior Femoral Region

Of the three leg flexors, we find the *semitendinosus* and *semimembranosus* muscles near the inner border of the thigh, nearly in the middle of the thigh; and the *biceps femoris* muscle, generally only a little outward from it.

These three muscles usually require strong currents for their stimulation. The effect of the stimulation is, as a rule, only a springing into relief of their muscle bellies and tendons: the tendon of the biceps, at the outer border; those of the semi-muscles, at the inner border of the hollow of the knee. Usually we see nothing

at all, or very little, of the leg flexion with electrical stimulation.

Muscles of the Posterior Tibio-Fibular Region

The *gastrocnemius* muscle is usually excitable at several points below the knee-cap, generally better in its lateral portions than in its middle. We see that it causes plantar flexion of the foot, which turns the foot with the toes inward.

The *soleus* muscle may be isolated occasionally below at its lateral portions not covered by the gastrocnemius (see Fig. 24).

Stimulation of the *flexor hallucis longus* muscle, on the outside next to the tendo Achillis at its lowest part, flexes the terminal phalanx of the great toe.

Stimulation of the *flexor digitorum communis longus* muscle, on the inside close to the lower tibial point, next to the tendo Achillis, flexes the toes.

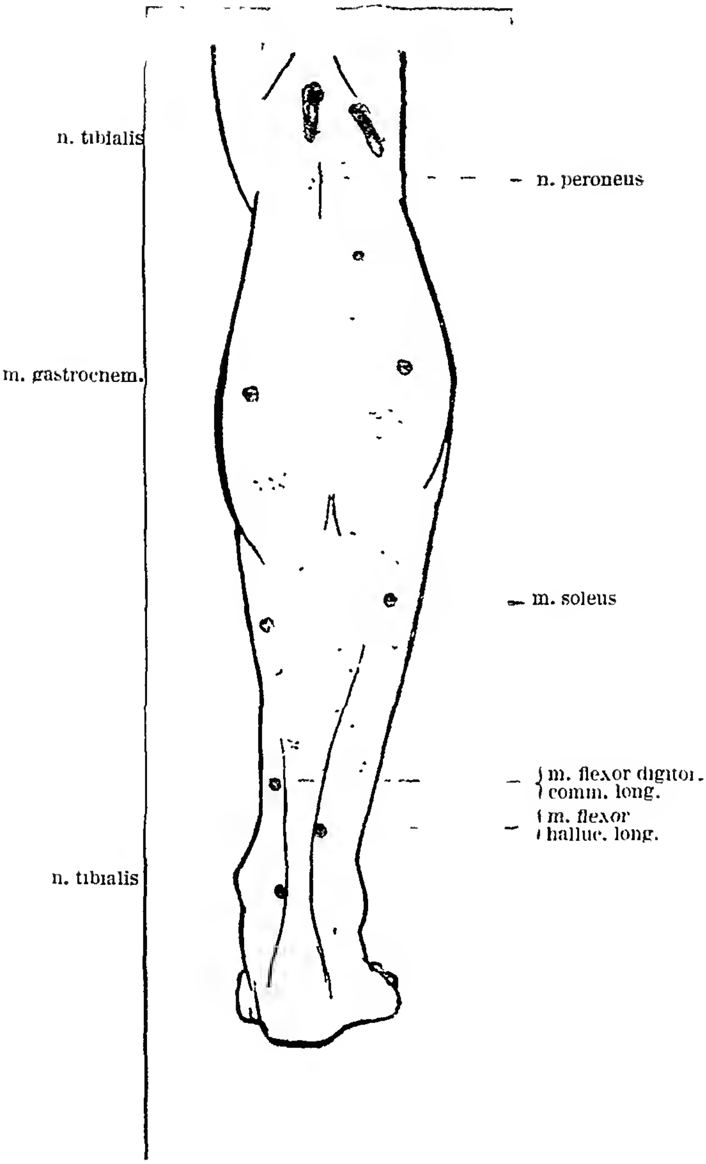
The *planta pedis* muscles can be isolated in but few cases and only with very strong currents. Since they very seldom have a practical interest, they need not be mentioned.

Method of Investigation

The method for an electrical investigation, according to what we have said above, is the following:

Let us take as the simplest example a diseased single muscle of one half of the body—*e.g.*, the left extensor digitorum communis brachii muscle. The investigation begins on the healthy side of the body with the search for the healthy muscle—that is, in our example, the right extensor digitorum communis. We place an indifferent plate electrode, well soaked with warm water, on

PLATE VIII.


n. tibialis
n. peroneus
m. gastrocnem.
m. soleus
m. flexor digitor. comm. long.
m. flexor halluc. long.
n. tibialis

the sternum, or in the neighborhood of the sacrum, or at the neck, in which case an especially adapted neck electròde (Fig. 25) may be used. This electrode is either held by the patient against the sternum with the hand which is not being examined, or it is fastened in the collar or in the clothing surrounding the hip, so that it lies directly on the skin. (Be careful that part of the clothing is not pushed in between.) From time to time we must see, in the course of lengthy investigations, that the electrode is sufficiently moistened. One immersion in

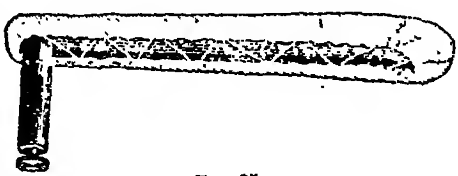


FIG. 25.

water does not suffice, but a thorough soaking is necessary (particularly with new electrodes).. Also we must be sure that the screw of the electrode is well fastened at the end of the conducting-cord, and that also the other end of the conducting-cord is tightly secured; then we chose the exciting-electrode, which it is always best to have provided with an interrupter. The diameter for purposes of investigation is usually 3 sq. cm. (normal electrode of Stintzing, see page 55); only at several points, which are specially named in what has been discussed above, is one of smaller diameter useful. The diameter of this electrode must be noted in the report—that is: Elect. dia. = 3 sq. cm. This electrode should also be well moistened, and we should be sure that the inter-

rupter is in good working condition, since the interposition of a drop of water or of a tiny hair interrupts the operation by causing a lingering current closure, even with the interrupter opened, or with the interrupter closed.

Procedure Then send the faradic (secondary) current (see page 28) through the common binding-posts by (1) moving the handle of the changing-apparatus to *S.*, (2) excluding the rheostat entirely, and (3) plugging the block *J.*, when at once there begins a buzzing sound called forth through the Wagner-Neef's hammer. Let the distance between the secondary and the primary coil be maximal at first, thus producing a minimal current. Now place the exciting-electrode opened on the muscle to be examined, and press down the spring with the thumb on the interrupting-handle. In doing this, hold the electrode in the entire fist, not like a pen. We set it first on the point of the muscle, which, by supposition or by experience (see the Plates, Nos. 17–24), is the most excitable, while we slowly push the secondary coil over the primary with the free hand: thus gradually increasing the current, we make a current closing with the engaged hand by the use of the interrupter—namely, through rapid lifting of the thumb from the interrupting-handle, as the secondary coil passes over the primary coil, and we assure ourselves each time whether the muscle reacts—that is, if a contraction follows. That the muscle must be relaxed has already been emphasized above (page 54, where also the methods of accomplishing this were given).

The pole that usually we make use of is the Ka. for faradic stimulation, altho as a rule it is not important to pay attention to this.

Quality of Contraction

As soon as we see a contraction of the muscle, we should determine, first, its quality, that is, if it is tetanic—occurring with a jerk immediately after a current closing and disappearing with a jerk after current opening—or if there is anything abnormal in the contraction.

We should try, by moving the secondary spiral slightly, to determine if the observed contraction is really the minimal contraction—that is, to find that position of the spiral in which the minimal (in other words, the first perceptible) contraction occurs. And when we believe we have found what we were looking for, then, by applying the electrode with interrupter opened, so that it touches various other points of the muscle in the neighborhood of the one just found, and by making one or two closings at each of the same, or by drawing the closed electrode over the entire muscle causing it, we must try if we can not with the former minimal current strength get a greater contraction at other points. Where the greatest contraction occurs with the least current there is the actual point of greatest excitability. It is best to mark this point by drawing a mark around the disk of the applied electrode with a dermatographic pencil, or to hold the electrode unmoved on the point, till the entire investigation is finished. Even a slight moving or bending alters the results.

Point of Greatest Excitability

When we have determined in the way described the minimal contraction, we note, in the table soon to be

mentioned, the coil distance (*C.D.*) at which this contraction was seen, reading it in millimeters on the scale.

E.g.: Right Extensor Digitorum Communis Muscle, Faradic: 120 mm. C.D.

In addition, we should note the possible qualitative changes. If the quality is normal, it need not be mentioned.

Now we exclude the faradic current and send in its place the galvanic (constant) current from the common binding-posts by turning the handle of the current-changer to *C.*, the rheostat to 0, and we remove the plug and bring in any desired number of cells by means of the cell-collecting switch.*

Now by means of the current-reverser we change the exciting-electrode to the Ka. (because in normal conditions with Ka.Cl. the first contraction is observed).

It is advisable, in order more easily to avoid errors, that one have different colored conducting-cords, so that he may fasten once for all the black cord on the + binding-post, the red cord on the — binding-post, and connect the interrupting-electrode with the red cord; then placing the current-reversing handle in a normal position (on *N.*), he will find that the exciting-electrode is the Ka.

Use of Rheostat

Then we push the handle of the rheostat, clockwise, slowly from contact to contact, at the same

*In testing muscles or nerves which experience has shown to be easily excitable, we choose usually a small number of cells (five, ten, fifteen); with others more difficult to excite, a greater number. Recently it has been recommended to note particularly the number of cells used, the electromotor force produced by them; that is, tension or intensity measured by means of a voltmeter (see page 12, footnote).

time making closings and openings at the interrupter, till at one of these excitation moments (normally at the closing) we see a decided muscle contraction, when we should notice exactly the character of the contraction and observe closely whether in reality it is lightning-like (see page 43) or not. By turning the handle back and forth slightly, we should assure ourselves if the contraction is, in fact, minimal. If this is not the case, we push the handle back to the point at which we produced the slightest perceptible contraction, and now while we leave closed the interrupter of the electrode which is *applied to the muscle we release the galvanometer needle* so that it sways freely, and let it swing until it rests, which is accomplished usually after a few seconds. We then read from the galvanometer the current strength which the needle indicates, and note it on the table. *E.g.: Ka. Cl. C. 1.5 ma. lightning-like (l.) or prompt (pr.).* Thereon we open the interrupter by pressure of the handle (by removing the finger from it).*

Character of Contraction

Reverse the current direction by means of the current-reverser; in doing which we have changed the exciting-electrode to An. Without changing the position of the cell-collecting switch, or of the rheostat—in short, without altering the current strength in any way—close the interrupter again to determine whether a contraction is visible with An. Cl. or An. O. In case there is, we turn

Use of Current-Reverser

* Without moving the electrodes at all, and by reversing when the current is closed, both (1) the skin resistance and (2) the muscle excitability will be changed, so that the results then obtained will not be comparable without further investigation.

the rheostat handle back to the point where we see the minimal contraction with An.Cl. or An.O., and note the number of milliamperes which accompanies this. In the other case we strengthen the current gradually by turning the handle farther, clockwise, until the minimal contraction occurs, and we note this strength; *e.g.: An.Cl.C. 3 ma. An.O.C. 3.5 ma.*

Form of Contraction

Here, too, the form of the contraction must be noticed. It sometimes occurs that the An. contractions have a character different from that of the Ka. contractions.

Now open the interrupter again, turn back to the Ka. and determine in the same manner the minimal Ka.O.C., respectively the Ka.Cl.Te. Note this current strength also in the table; *e.g.: Ka.Cl.Te., 5 ma.; Ka.O.C., 7 ma.*

With this the investigation of the muscle is ended, and we can remove the exciting-electrode, after first turning all handles of the apparatus to the 0 or starting-point.*

We proceed in exactly the same manner now with the symmetrical muscle on the other side of the body; in doing which we should remember that symmetrical muscles have not always their excitation-points placed with exact correspondence, so that it is necessary each time to begin the examination of the second half of the body with the above-described search for the most excitable

* The entire galvanic investigation must not proceed too slowly, because the exactitude of the results is destroyed by the change of resistance, caused by the long application of the galvanic current.

point. These results also we note in the table, which will then appear somewhat as follows:*

The Report

Elect.-Dia. = 3 sq. cm.	RIGHT.		LEFT.	
	Faradic.	Galvanic.	Faradic.	Galvanic.
Extensor digitorum communis muscle	120 mm. C.D.	Ka.Cl.C.—1.5 ma. An.Cl.C.—3.0 ma. An.O.C.—3.5 ma. Ka.Cl.Te.—5.0 ma. Ka.O.C.—7.0 ma. Lightning-like.		
Extensor pollicis longus muscle.				

"Condensed Method"

For practical purposes investigation in this complete manner is superfluous. We substitute a "condensed method" that fully suffices in the greater number of cases. The faradic investigation is made in the manner presented above, as is also the determination of the Ka.Cl.C. Then as above, open (the interrupter), reverse (the current by means of the current reverser), close (the interrupter), and merely observe if, in fact, as it should be normally, the Ka.Cl.C. occurs earlier than the An.Cl.C.—that is, if, with the same current strength just now at hand, an An.C. (immaterial if An.O.C., or An.Cl.C.) occurs. If this is the case, then we have an abnormal condition before us, and we must determine the minimal An.C. and note in the above-described manner. If this, however, is not the case and the action is normal, then by moving the rheostat handle forward we

* There are different formulæ for electro-diagnostic tables: the one here presented seems to me the most easily readable.

determine whether an An.C. occurs with strong currents without taking into account its minimal current strength. In this case it suffices to note, *e.g.:* Ka.Cl.C. 1.5 ma. lightning-like >An.C. (that is, greater than An.C.).

This shows clearly then, for practical purposes, that the contraction form in the foregoing case presents no decided deviation from the normal.

The abridged table of the above imagined case will read, therefore:

Elect.-dia. = 3 sq. cm.	RIGHT.		LEFT.	
	Faradic.	Galvanic.	Faradic.	Galvanic.
Extensor digitorum communis muscle	120 mm. C.D.	Ka.Cl.C.—1.5 ma. > An. contraction Lightning-like.		

Details that are noted during the examination must likewise be noted in the table. Concerning this, see farther on.

By comparing both sides of the table we will easily be able to find our bearings in regard to any deviation from the normal, provided that it is a case of one-sided affection. In cases of two-sided affection we should use the Stintzing Normal Tables, as detailed above.

In the same manner we proceed with the investigation of motor nerves. There we must also notice if all the muscles supplied by the nerve in question react to nerve stimulation. Eventually we must note those which do not.

CHAPTER IV

CHANGES IN THE REACTION OF THE MUSCLES AND MOTOR NERVES

It has already been discussed in the beginning of the foregoing chapter that we naturally differentiate three kinds of reaction changes in pathological conditions of the muscles and motor nerves: (1) Quantitative (concerning the excitability in the true sense—that is, the minimal contraction): (2) qualitative (this concerns the contraction form); (3) the quantitative-qualitative.*

* Another principle forms the basis of the division that Doumer proposed for the changes in the electrical reaction. He views the pathological reaction anomalies not as separate things, but as symptom complexes (syndromes) and separates them, as it were, into their components: "elemental, single reactions." He distinguishes the following reactions: (1) For the faradic current: (*a*) increased excitability, and (*b*) decreased excitability (Duchenne's reaction). (2) For the galvanic current: (*a*) increased excitability, (*b*) decreased excitability, (*c*) change in the relative values of Ka. closing and An. closing (Erb's reaction), (*d*) change in the relative values of Ka. closing and Ka. opening (Rich's reaction), and (*e*) loss of the nerve excitability with retained muscular excitability with parallel currents (longitudinal reaction).

In anomalies of muscle contraction Doumer differentiates:

(*a*) Shortening of the latent period.

(*b*) Lengthening of the same.

(*c*) Shortening of the contraction duration.

(*d*) Lengthening of the same.

(*e*) Changes of the curve form (spastic, paralytic, atrophic, degenerative curve, according to Mendelson).

The purely qualitative changes in reaction are very rare and, therefore, will be considered in the Appendix.*

Quantitative and Qualitative Changes

The practitioner is interested principally: (1) In the purely quantitative changes (and of these again in the simple diminution of excitability, since a simple increase of excitability is also infrequent), and (2) in the quantitative-qualitative changes, particularly in the different forms of the reaction of degeneration.

To facilitate the understanding of these changes we must begin further back with several fundamental facts, which concern the anatomy and physiology of the motor conduction-path.

The Motor Conduction Path

In the motor region of the cerebal cortex corresponding to the central convolution, there are the large so-called pyramidal cells. These cells have processes: (1) a row of short processes, that usually lie near the cortex, protoplasmic processes or dendrites, and (2) a single long process that extends toward the periphery, the axis-cylinder process (nerve-process, neurit, or axon). This latter goes through the white hemisphere substance, through the internal capsule (posterior limb), through the pes pedunculi, the pons, and the medulla oblongata, as fibers of the pyramidal path, consisting only of such neurits. In the most caudal part of the medulla oblongata this cell process crosses a symmetrical one from the opposite side, at the pyramidal crossing, and then courses downward on the other side of the body into the lateral columns of the

Axis Cylinder

(*f*) Exhaustion reaction.

Exact and scientifically valuable as this division is, still, as it has not yet been generally adopted in practise, the old division is retained in what is to follow.

* The much-used expression "qualitative" change in "excitability" contains a contradiction in words, since excitability denotes a purely quantitative thing as present. We can speak only of the qualitative change in the reaction or contraction.

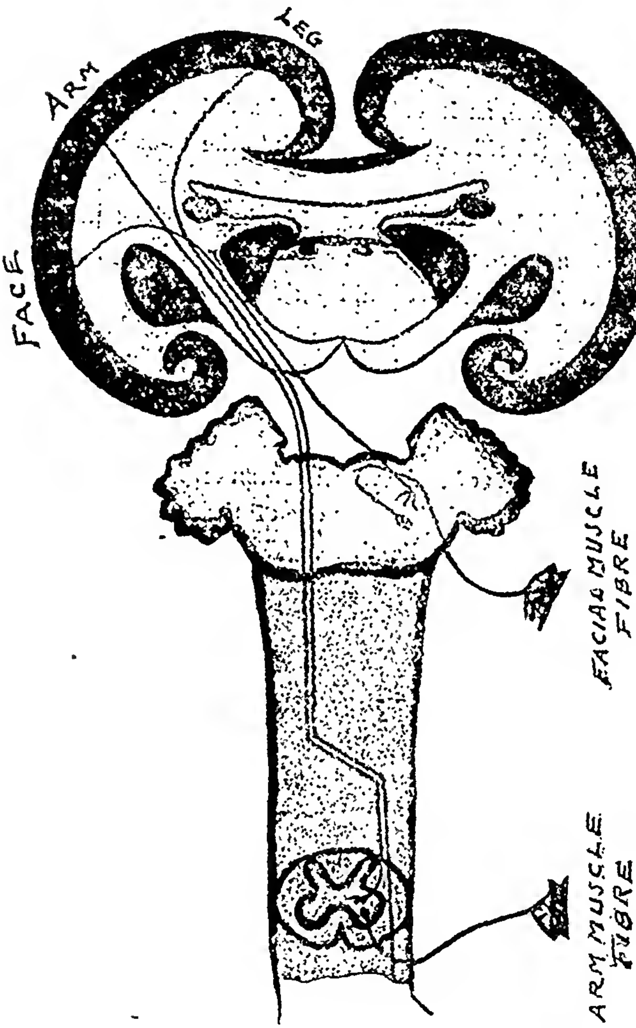


FIG. 26.—Diagram of the Motor Conduction Pathway, from the plates of Strümpell and Jacob.

cord as a constituent part of the lateral pyramidal column tracts (*L. Py. T.*),* and only later crosses somewhere in the cord—sometimes

* A few fibers also pass uncrossed in the front columns, as anterior pyramidal tracts (*A. Py. T.*).

higher, sometimes lower, according as the impulse is carried to a muscle of the arm, the leg, etc. It turns out of the vertical direction into the horizontal, as it enters into the anterior horn, and there, arrived at the end of its course, splits into the so-called terminal arborization.*

Central Motor Neuron

The pyramidal cells, together with their various processes, we designate as a nerve unit or neuron, and as cortico-spinal or central motor neuron (archineuron Waldeyer).

While the dendrites probably have the function of conducting excitability to the cells—that is, are "cellulipetal"—the conduction in the axis-cylinder processes is "cellulifugal." The motor impulses are therefore conducted by the neurits from the cell to the periphery.

Anterior Horn Cell

The end-branches of each central neuron enter in the anterior horn into contact-like association with one of the large polygonal motor anterior horn cells that lie there. They either surround the cell itself, claw-like, without, however, blending with it, or they touch the dendrites of this cell.†

Peripheral Motor Neuron

This cell likewise sends forth processes: (1) Numerous dendrites that have a short course and conduct stimulation cellulipetally; (2) a single axis-cylinder process, that goes through the anterior horn into the anterior roots as filaments of these roots, and then proceeds as a peripheral motor-nerve to a muscle-fiber. Arrived at the muscle-fiber, it branches at its end and enters into contact-like association with the muscle-fiber. The anterior horn cell, together with its processes, forms another nerve unit or neuron, which is designated as spino-muscular or peripheral motor neuron (teleneuron, Waldeyer).

The motor conduction-tract of the cranial nerves, like that of the spinal nerves, consists of two neurons. The central neuron has its

* The collateral branches that it gives off on the way need not be considered in this discussion.

† A sort of blending has lately been supposed to exist. This neuron theory is vigorously attacked by Bethe, Apathi, Held, Nissl, and others. For the present, however, it has at least value to the extent that we may retain the nomenclature created with it as the form of expression for electro-diagnostic uses.

cell in the cortex surface (in the most basal portion of the central convolutions) in the neighborhood of the facio-lingual center near the Sylvian fossa; the axis-cylinder of this cell goes through the narrow white substance, the internal capsule (posterior limb), and then through the pes pedunculi down into the pyramidal tract, but crosses above the real pyramidal crossing, in the pons or in the upper part of the oblongata, with the symmetric filament of the other side of the body. After crossing, it goes to the nucleus of the particular cranial nerve on the opposite side, to which it conducts the impulse (facial, hypoglossus, etc.), and there splits into the end-branches. The end-brauches enter then, in the above-described way, into contact-like association with the cell of the motor nucleus, without blending with it.

Motor Conduction-Path of the Cranial Nerves

With this cell begins the peripheral motor neuron of the cranial nerve conduction-tract. The axis-cylinder process of this cell continues as a filament of the outgoing cranial nerve-root, toward the base of the brain, and farther as peripheral cranial nerve-filament to a muscle-fiber; reaching this it splits into end-branches. From this presentation appears the important fact that the cell of the nucleus in the cranial trunk for the cranial nerve has the same physiological significance for the cranial nerves as the anterior horn cell for the spinal-cord nerves. But something more, very significant for our theme, will be easily understood from what has just been said.

Peripheral Motor Neuron of the Cranial Nerve Conduction-Path

If one of the two neurons which form the motor conduction-path is interrupted at some point by an injury or a disease process, or if the cell belonging to one of the two becomes diseased, the axis-cylinder of the affected neuron undergoes an anatomical change that leads to its final destruction, and is called degenerative atrophy, or, in short, degeneration. The axis-cylinder loses first its surrounding envelope, in that the medullary sheath falls in flakes, pieces, or crumbs; then the

Degeneration

axis-cylinder itself disintegrates likewise, the nuclei of the sheath of Schwann are increased, the interstitial tissue increases also and takes the place of the disappeared nerve tissue—as it were, a "cirrhosis of the nerve."

Neuron Degeneration

This degeneration concerns only the neuron in which the changes due to disease occur. The rest of the motor conduction-path remains intact. This is a fundamental fact which we must remember first of all, and which clearly follows from the anatomical independence of the nerve unit.*

But—and this is the second fundamental rule—if the peripheral, the spino-muscular neuron, degenerates, then the associated muscle-fiber also becomes diseased. It also suffers a degenerative atrophy: it becomes smaller, losing its transverse striation; the nuclei of the sarcolemma increase. There occur chemical alterations in the sense of a necrobiosis (wax-like degeneration, etc.); the interstitial connective or fat tissue luxuriates and increases and takes the place of the disappearing contractile substance; finally, "cirrhosis of the muscle-fibers" occurs.

Muscle-Fiber Degeneration

Simple muscular atrophy is found not only in diseases of the muscles themselves, but also in a whole series of other disease forms which will be mentioned hereafter. The degenerative atrophy of the muscle does occur when the peripheral neuron—its cells or their axis-cylinder process—is injured or changed by disease.†

Simple Atrophy

The degenerated muscle reacts to the electrical cur-

* Apparent exceptions to this rule will be gone into later.

† In general this proposition can be held as correct, despite contradictory discoveries.

rent in another manner than one that is not degenerated, and also otherwise than one that is simply atrophied. Thus by means of the electrical investigation we can prove muscle-degeneration. The reaction of the muscle in such cases we designate with Erb as REACTION OF DEGENERATION (D. R.).

The Law of D. R.

The D. R. will be found then when the peripheral motor neuron is diseased to a considerable extent. It is not found in diseases of the central neuron, or of the muscle itself, or of other parts of the nervous system and the rest of the body. *When the D. R. is present, it is a sign that a disease process is going on in the region of the peripheral neuron.*

It is well for the beginner to regard this sentence as a fundamental proposition—a rule without exception. The fact should be mentioned, and later on will be more fully discussed, that discoveries have been made which tend to limit decidedly the application of this rule.

The diseases in which we find the other changes in the electrical reaction, particularly the simple quantitative or simple qualitative changes, concerning other parts of the motor conduction-tracts and the motor apparatus, will be more fully discussed in the following.

(A) The Purely Quantitative Changes.

If a muscle or motor nerve reacts with the minimal contraction to currents weaker than for the normal, we call it increased electrical excitability.*

* The increase may concern either the faradic or the galvanic excitability, or both. The latter is the more frequent, but the former also occurs frequently.

Increased Excitability

The increase of excitability appears in one-sided affections, so that on the affected side a faradic contraction is observed with a greater coil distance (that is, a weaker strength of the faradic current) than on the healthy side. The increase of the galvanic excitability shows itself in the fact that a contraction is produced on the diseased side by a smaller number of milliamperes than on the healthy side. In double-sided affections we can recognize an increase of the excitability if the values of the current strength with which the minimal contraction in a muscle or nerve becomes visible lies below the lowest limit of the Stintzing minimal value; we can assume the increase when the value lies near the Stintzing minimal value and if the part in question is diseased. Particularly instructive and convincing in such cases is the investigation with the galvanic current, taking into consideration the contraction laws. We find in typical cases of increased excitability that not only, *e.g.*, Ka.Cl.C. occurs with fractions of a milliampere, but that the An.Cs. occur with currents not much stronger, and that the Ka. O.C., or even Ka.Cl.Te., occurs with current strengths by which normally we hardly produce a Ka.Cl.C.; but if we increase the current still more, we can, with currents not particularly strong, see reactions which in the normal muscles would occur only with current intensities so great that they are not generally used in practise —namely, An.Cl.Te., An.O.Te., or, as I once saw in a case of tetany, Ka.O.Te. Here we should remember that it is not a question of the qualitative change in the normal contraction schema, but to a certain degree

Typical Cases

only a more rapid occurrence of the same. The succession in the occurrence of any single contraction factor remains the same, and the form of the contraction, too, in pure increase of excitability is normal, lightning-like.

The pure increase of excitability is nearly a *pathognomonic* sign of tetany. It concerns almost invariably both current qualities, seldom the galvanic current alone. Its presence makes possible a differential diagnosis between real tetany and similar diseases, with an approximate certainty in doubtful cases, especially certain hysterical conditions, due to contractions occurring spasmodically in the muscles of the forearm and the leg. In the latter cases we usually do not find increase of the electrical excitability.

Pathognomonic Sign for Tetany

In children, in whom tetany frequently occurs, it is sufficient, in order to confirm the diagnosis, to show that in one nerve, the median nerve, the Ka.Cl.C. occurs with less than 0.7 ma., the Ka.O.C. with less than 5 ma. Very often in such a case the An. O.C. > or = An.Cl.C. (L. Mann). The possibility of producing without difficulty galvanic An.Te. (or even Ka.O.Te) likewise indicates true tetany. The increase can affect muscles as well as motor nerves. The part of a report of an investigation, given on page 106, offers an example of such a case (a nineteen-year-old young man affected with true tetany).

Indicates True Tetany

Besides tetany, there are isolated cases of cerebral paralysis (recent or strongly spastic hemiplegia) in which simple increase of the excitability was found; and also several observations of tabes dorsalis in the first stages

and several peripheral nerve palsies (facial and radial); in the latter cases increase in excitability lasted for days or weeks.

Far oftener than increase we get the opposite change, the pure diminution of excitability. If a motor nerve

Decrease of Excitability

Elect.-dia. = 3 sq. cm.	Right.		Left.	
	Faradic.	Galvanic.	Faradic.	Gal-vanic.
Biceps brachii muscle.	By greatest C. D. decided (not minimal) contraction.	Ka.Cl.C.—$\frac{1}{8}$ ma. An.O.C.—$\frac{1}{4}$ ma. An.Cl.C.—$\frac{1}{4}$ ma. Ka.Cl.Te.—$\frac{1}{3}$ ma. Ka.O.C.—1 ma. An.Cl.Te.—3.5 ma. An.O.Te.—about 4 ma. Ka.O.Te. — with currents over 7 ma. Lightning-like contractions.		

or muscle shows the minimal contraction only with current strengths greater than the normal, we speak of it as decreased excitability. This disturbance also affects either one or both kinds of current (the latter more frequently); and again, the change is proved by comparison with the healthy side in one-sided affections, and with the help of the Stintzing tables when both are affected. With the galvanic current, a larger number of milliamperes, and with the faradic, a current of smaller coil distance (*i.e.*, greater strength) is required to produce the minimal contraction on the diseased than on the healthy side of the body, or in healthy individuals. The galvanic contraction formula is unchanged and the character of the contraction is normal.

We find the decreased excitability without qualitative abnormality in a number of morbid conditions which formerly were treated collectively under the name of atrophies from disuse, but which now often rightly receive an entirely different explanation. To these belong, *e.g.*, the atrophies that appear in joint affections (in muscles that are contiguous to the diseased joint), also those that appear with luxations and bandage fixation (*e.g.*, after operation for phlegmon), and those that appear in fractures near the joint. We can designate them, briefly, arthritic or (as they often are named) "reflex atrophies."* Reflex Atrophies

If in such atrophied muscles any electrical change can be demonstrated—which is not by any means always the case—it is simply diminution. As soon as the reaction of degeneration shows itself, we must assume a complication, *e.g.*, a neuritis of a neighboring plexus.

There are also to be mentioned here the atrophies following cerebral paralysis—that is, in the region of the central motor neuron, in apoplexies, softenings, etc., with resulting mono-, hemi-, or diplegias. If any electrical change is to be found in these, it is also only a quantitative change (mostly decrease of the excitability). In many cases of this kind the electrical excitability is normal throughout. Cerebral Atrophies

In regard to the significance of the seeming qualitative change

*The most widespread conception is that in the joint disease alterations are produced reflexly in the anterior horn-cells, which are not marked enough to be anatomically proved at the time, but still sufficient to cause simple muscular atrophy of the kind described, reflex trophoneurosis. This view is supported experimentally, but still remains an hypothesis.

in the contraction form that is called forth in such muscles through the contraction (faradic "pseudo"-contraction tardiness) see page 137.

Column Diseases

Also in the other diseases in the region of the central motor neurons, in which the peripheral neurons remain intact—that is, in the column diseases of the spinal cord (spastic spinal paralysis, myelitis, multiple sclerosis, and in certain hemorrhages, softenings without involvement of the anterior horns), in diseases of the pedunculi cerebri, and of the pons and the oblongata (without damage to the gray matter and the motor cranial nerves), there is either no electrical abnormality or mostly simple diminution, for both currents or for the faradic alone, seldom for the galvanic alone.

Atrophies from Disuse

Simple diminution, furthermore, accompanies a number of atrophies, whose genesis is unknown (perhaps they really are atrophies). These are the atrophies in certain cases of tabes and functional neuroses, particularly hysteria. In these latter cases exact determination of the electrical conditions is especially important if it is a case of hysteria of traumatic origin, and if the question of simulation or aggravation is to be answered, because damages for an accident are claimed by the patient. A positive result of the electrical test—that is, the finding of positive diminution of excitability—will permit exclusion of simulation; a negative result, however, permits of no conclusion.

Finally the diminution of excitability, with a normal condition in the quality of the contraction, is also a characteristic accompaniment of atrophies which owe

their origin to a disease of the muscles themselves (that is, of the peripheral ends of the motor spheres). It is principally the different forms of progressive muscular atrophy or myopathic progressive muscular atrophy (in contrast to spinal progressive muscle atrophy so named) that come into consideration here. These are the pseudo-hypertrophic, the juvenile, the infantile, the Landouzy-Déjérine form of myogenic atrophy, all of which are collectively designated by the above name. Here the determination of the electrical reaction frequently has a direct differential diagnostic significance, especially when it is doubtful if a progressive atrophy is of muscular or spinal origin—that is, is due to disease in the anterior horns. Whereas in the muscular forms there is either no electrical alteration or only a simple diminution (at one time small, at another time so great as to amount to extinction of excitability, still in every case always purely quantitative); in the spinal diseases, in which it is a *question of changes in the region of* peripheral neurons, there usually occurs reaction of degeneration. In these cases we shall be able to make a local diagnosis.

Dystrophies

Of course it should not be overlooked that even in cases of spinal origin the reaction of degeneration is often not present, or present only at isolated points; for, when a spinal atrophy proceeds slowly, so that in the muscle under investigation fiber by fiber is destroyed, and the fibers that are actually undergoing degeneration at one time form a small minority, and the same current finds either "an overwhelming majority" of intact

Slowly Progressive Spinal Atrophy

fibers or of fibres that have fully changed to connective-tissue (sclerosed muscle-fibers), in many cases a reaction of degeneration will rarely appear. There will rather be quite a normal excitability in the muscle in which the process of atrophy is beginning—however, a muscle in which the process is advanced, in proportion to the number of contractile parts present, will show either simple diminution or loss of excitability.*

Differential Diagnostic Value of D. R.

This phenomenon we actually find in many cases of progressive muscular atrophy, in chronic poliomyelitis, in amyotrophic lateral sclerosis, in progressive bulbar paralysis, etc. In such cases the gist of the matter is that an electrical examination has a differential diagnostic value only when D. R. is actually found. If in doubtful cases the investigation shows simple diminution without qualitative changes, then a muscular disease is probable, but not certain; if it shows the D. R., then in general we may assume that a spinal disease is present.

There are, in the literature of the subject, several cases of what to all appearances is positive myopathy—described as progressive muscular dystrophy—in which D. R. was found. This would contradict the law set forth above, which states that D. R. occurs only in diseases of the peripheral neuron. The case sare certainly few, still they are to be taken into consideration. So far we have not drawn from them the conclusion that there are positive exceptions to the law named; now we rather incline to the acceptance that between the spinal and the muscular forms of progressive atrophy transitional stages may exist, so that there is no sharp boundary be-

* I know that this statement is open to attack, and I state positively that it is only hypothetical So long, however, as we know no better one, it may serve to help the beginner to understand the matter.

tween them, and that even the so-called muscular forms may, perhaps, be traced to affections of the anterior horns—not demonstratable with our present methods In general, what we have said above in regard to the differential diagnosis holds good in spite of these isolated observations. In regard to the differential diagnosis between spinal and cerebral paralyses of children, see page 115. In the next division will be discussed more fully the fact that, after the disappearance of severe degenerative peripheral paralysis, diminished excitability, without qualitative disturbances, may remain for a very long time as the sole electrical change.

The Degree of Diminution

In regard to the degree of the diminution in various diseases it is generally slight in real atrophies from disuse. Here the diminution also is limited very often to the faradic current alone, and in these cases we must be particularly cautious in making the diagnosis of "diminished excitability." It lies in the nature of the methods of the investigation that, in determining the faradic minimal contraction of two symmetrical muscles, slight differences will be found even in entirely healthy persons. There is difficulty in seeing minimal contraction, and the beginner frequently gets false results if he is not careful to have the muscles which are examined relaxed, or if the point at which he is examining them is not the most excitable. If during the investigation the electrode plate becomes dry, or if it is slightly displaced or turned over, the results of the examination will be altered. And, furthermore, we must remember that in quite healthy persons there are anatomical differences between symmetrical parts of the two sides of the body. If as a result of such anatomical variation the motor nerve which is being investigated lies considerably

Anatomical Differences

deeper on one side than on the other, so that it has a thicker covering of electrical conducting-tissue over it, in this covering tissue a larger fraction of the current (in any case a greater fraction than on the other side) will be lost by the formation of current streamers before the current reaches the nerve. Therefore in the deeper-lying nerve the excitability will seem to be diminished, tho this is not actually the case. The same thing may happen if the subcutaneous fat-tissue is more developed on the one side than on the other (L. Mann), or if there is a collection of fluid (edema) in the subcutaneous tissue.

Necessity for Reexamination

Summing up, we must say that slight diminution of excitability—that is, a difference of a few millimeters coil distance (C. D.), or fraction of a milliampere must be verified through repeated reexaminations before it can be recognized as pathological, especially if the disturbance does not affect both kinds of currents in the same manner, or if in a larger equally diseased region the various muscles or nerves show entirely different results, *e.g.*, the one increase of excitability, the other decrease. Only when several investigations always give the same results may we speak with any degree of certainty of the decreased excitability. Double-sided affections naturally require particular caution. In this case we should diagnosticate a pathological process only when there are very considerable deviations from the Stintzing average values.

In diseases in the region of the central motor neurons, in hemiplegic atrophies, and the like, the diminution or increase of the excitability does not attain a significant degree. Since contractions frequently occur here, so

that a relaxation of the examined muscles is not possible for a length of time, we must be very cautious in using the minimum values.

The arthritic atrophies show occasionally a stronger degree of diminution; the greatest are found in progressive atrophies, and in the above-mentioned forms (page 110) of slowly progressive spinal atrophy. In this case the excitability for both kinds of currents decreases quite regularly more and more until it becomes extinct.

Absolute extinction of the excitability of the muscle shows that the contractile substance is not present in any considerable quantity in the muscle examined. This anomaly may be the final result of the D. R. or of the progressive diminution. Extinction of the excitability of the motor nerve in itself does not prove anything in regard to the anatomical condition of the muscle supplied by it. Direct muscle examination is required for that. We shall discuss this further in the next division.

Extinction of Excitability

(B) The Quantitative-Qualitative Changes.

Reaction of Degeneration (D. R.).

When those diseases in the region of the peripheral neurons which lead to muscle degeneration exceed a certain minimum degree, we usually find an abnormality in the electrical reaction of the nerves and muscles in question, whose essential characteristics are:

Definition of Reaction of Degeneration

(1) Quantitative changes—namely:

(*a*) A sinking and extinction of the (faradic and gal-

vanic) excitability of the nerve and of the faradic excitability of the muscle.

(*b*) Now an increase, now a decrease of the galvanic excitability of the muscle.

(2) Qualitative changes, particularly:

(*a*) Tardiness of the galvanic muscle contraction, and eventually

(*b*) Deviations from the normal course of the contraction laws.

This complicated anomaly of reaction which accompanies the anatomical change in muscle degeneration and which is restored in a certain natural manner to a normal condition, when the muscle degeneration gives way to a regeneration, has been discussed, after Baierlacher's preparatory work, by Erb (1868). Tho it was studied first by Ziemssen and Weiss, Erb first designated it by its present name of "reaction of degeneration" (D. R.).

The Occurrence of D. R.

The disease conditions in which the D. R. may occur are, as can be easily understood from the above (see scheme of the course of fibers, page 99, Fig. 26) essentially the following:

Diseases of the Medulla

(1) Diseases of the medulla oblongata, *i.e.*, of the brain stem with involvement of the gray muclei of the cranial nerves; also the different forms of bulbar paralysis (acute, chronic, progressive), hemorrhages and softenings in the brain stem, etc.; also hereditary or early acquired cases of facial paralysis, of which, of course, only a part is of nuclear origin, also belong here. In these cases the D. R. is found only in the region of the affected cranial nerve. If the pathological process should

also affect at the same time the fibers of the pyramidal tract, which run through to the spinal nerve, in spite of this, their disease condition would not lead to D. R.

(2) Diseases which attack the anterior horn cells of the spinal cord: poliomyelitis anterior acuta (*e.g.*, "infantile spinal paralysis" *), subacuta and chronica, as well as progressive spinal muscular atrophy †; while, as has been said above (page 109), D. R. is usually missing in myopathic muscle atrophy. Furthermore D. R. is present in hemorrhages and softenings in the anterior horn; in formation of swellings, especially gliomatous (syringomyelia, Morvan's disease); in inflammation of the entire transverse area of the spinal cord (transverse myelitis); and in the amyotrophic lateral sclerosis, anterior-horn and lateral-column disease (lateral-column affection alone, *e.g.*, the secondary descending, or those with combined system or idiopathic diseases, the so-called spastic spinal paralysis, whose anatomical substratum to be sure has not yet been demonstrated, will not lead to D. R.). Also diffused foci of an inflammatory or sclerotic nature, if they have their seat in the anterior horn, may cause D. R. in the muscles supplied therefrom.

Anterior Horn Diseases

(3) Diseases which affect the roots of the cerebral or

* The so-called cerebral infantile paralysis (seat in the cerebrum) shows no D. R., but either simple diminution or no anomaly at all. This may sometimes be of use in differential diagnosis.

† D. R. is also present, as a rule, in Hoffmann's neural form of muscle atrophy. The anatomical substratum is still a matter of dispute.

spinal nerves; meningeal diseases of different kinds, if they are associated with considerable involvement of the nerve-trunks; vertebral diseases of tuberculous nature, or tumors which originate in the vertebræ or meninges and constrict the nerves. These kinds of cases will probably be, on the whole, infrequent.

Peripheral Nerve Disease

(4) Diseases of the peripheral nerves themselves:

(*a*) Injuries, principally through bruising; with these belong the relaxing paralysis of the arm nerves; the peroneal pressure paralysis (*e.g.*, after child-bearing); the pressure paralyses of the ulnar, radial, and median nerves, which are caused by callus and tumor pressure; likewise those paralyses which occur in the nerves of the upper extremity through the carrying of loads, or during sleep. The so-called occupation-atrophies should also be noted here, as also the paralyses which result from cutting (saber thrusts, etc.), particularly often displayed at the nerves of the upper extremity, or which occur through operative separation, *e.g.*, at the facial in gland operations, the hypoglossus, etc., or through lacerations.

Of chemical injuries accompanied by D. R. there is to be mentioned paralysis after ether injection.

Particularly frequent is the "rheumatic" facial paralysis.

(*b*) Inflammations of the nerves. On the one hand, those that are secondary, as, *e.g.*, certain facial paralyses in diseases of the ear; on the other hand, the idiopathic, that are mostly either of toxic nature, as lead paralysis (this particularly prefers to affect the fore-

arm extensors*), arsenical and alcoholic neuritis; or of infectious nature, as diphtheritic neuritis, infectious multiple neuritis, or beri-beri; as well as neuritides occurring after influenza and typhus, etc.†

(c) Less frequently tumors of the nerves themselves.

We can distinguish different degrees and kinds of D. R. according to the intensity of the lesion—that is, according to a greater or lesser rapidity of its development. We can especially separate a complete form, in which the typical characteristics are most clearly seen, from a partial form, which presents, as it were, only a sketch of the symptom picture. The complete form includes—according to the prognosis of the underlying diseases—a "benign" and a "malignant" variety, of which we designate the first as curable, the later as incurable. The benign variety is divisible again into a slight and a moderate form, which are distinguished from one another only by their duration, and of which the slighter is rather infrequent. We can, then, in general distinguish the following types: Different Forms of D. R.

(1) Complete D. R.
  (a) Slight. } Curable cases.
  (b) Moderate. } Curable cases.
  (c) Severe.—Incurable cases.
(2) Partial.

* D. R. has also been found here in muscles which were not yet paralyzed or never became paralyzed. Isolated unexplained occurrences of this kind have been observed in several other diseases.

† The facial paralysis in so-called head tetanus does not occur with D. R. Its peripheral origin is doubtful.

To be sure, this distinction is artificial, and there exist between the separate forms numerous overlappings.*

The Course of D. R.

The following schematic table will illustrate the course of the separate forms of D. R.:

I. COMPLETE D. R.—SLIGHT AND MODERATE FORMS.

	INDIRECT (NERVE) EXCITABILITY.		DIRECT (MUSCLE) EXCITABILITY.	
	Faradic.	Galvanic.	Faradic.	Galvanic.
Stage 1, 1st week.	Toward the end diminished.	Toward the end diminished.	Somewhat later diminished.	Somewhat later diminished.
Stage 2, from about 2d to 15th week.†	Extinguished.	Extinguished.	Extinguished.	Increased, tardy contraction (An. > Ka.).
Stage 3, from about 6th to 12th week;† from about 16th to 30th week.†	Toward the end. Recurring.	Toward the end. Recurring.	Toward the end. Recurring.	Sinking to normal, more rapid contraction (An. = to or less than Ka.
Stage 4, later.	Normal or subnormal.	Normal or subnormal.	Normal or subnormal.	Normal or subnormal (no longer any qualitative change).

* Stintzing has presented thirteen different forms. They may not only be classified easily under the subheads of the above scheme, but we can also readily understand that such overlappings between the different forms may occur. It is doubtless best for the beginner to confine his attention at first to a few typical forms, which occur often, and only later to turn to those which deviate from the usual type.

† These numbers are only approximate.

II. Complete D. R.—Severe Form.

Stages 1 and 2 as in the above scheme, then follows:

	Indirect (Nerve) Excitability.		Direct (Muscle) Excitability.	
	Faradic.	Galvanic.	Faradic.	Galvanic.
Stage 3, 6th to 10th week.	Remains extinguished.	Remains extinguished.	Remains extinguished.	Sinking to extinction, remains tardy (An. > Ka.).

III. Partial D. R.

	Indirect (Nerve) Excitability.		Direct (Muscle) Excitability.	
	Faradic.	Galvanic.	Faradic.	Galvanic.
Stage 1, 1st week.	Normal, in- increased or decreased.	Normal, increased or decreased.	Normal, increased or (somewhat later) decreased.	Normal, increased or (somewhat later) decreased.
Stage 2, 2d to 5th week.	Normal or decreased.	Normal or decreased.	Normal or decreased.	Increased, tardy contraction (An. > Ka.).
Stage 3, 6th to about 12th week.	Becomes normal.	Becomes normal.	Becomes normal.	Becomes normal.
Or else (in diseases with slow or progressive course).				
Stage 3, 6th to 10th week.	Sinking until extinguished.	Sinking until extinguished.	Sinking until extinguished.	Sinking until extinguished, contraction remains tardy (An. > Ka.).

To understand the tables the following stages may be noted in which the relaxed paralysis of the radial nerve can serve as an example:

Division I.—Slight and Moderate Complete D. R.

Initial Stage

Stage I. Initial stage. The electrical changes do not occur at once, *e.g.*, immediately after receiving an injury, but a few days (from five to seven) later, as do likewise the visible anatomical changes of the nerves, and particularly of the muscles. About this time we find that both in the stimulation of the nerve itself (indirect stimulation), and in the stimulation of the separate muscles supplied by the nerve (direct stimulation), the excitability is simply diminished for both kinds of currents. To produce a minimal contraction, stronger faradic and galvanic currents are required than on the normal—that is, the healthy side. The form of the contraction is normal; the contraction law shows the usual course. Frequently diminution of the direct muscle excitability occurs somewhat later than the indirect—that is, about the beginning of the second week. Sometimes a temporary condition of increased excitability precedes the diminution of the muscle and nerve excitability.

Crisis Point

Stage II. Crisis point of disease. If we investigate the same nerve later (*e.g.*, the bruised radial, about in the second to the fifth week), it becomes apparent that its excitability as well for the galvanic as for the faradic current is entirely extinguished.*

If we now try the muscles directly supplied by the

* Usually the changes (diminution, extinction of the excitability, etc.) for the galvanic and faradic current in nerve stimulation and for the faradic in muscle stimulation take place nearly simultaneously. But in this direction also there are numerous exceptions of widely different kinds.

paralyzed nerve, we observe that these do not react to the strongest faradic current. On the other hand, they not only react to the galvanic current, but there is increased excitability (the minimal Ka.Cl.C. occurs with much weaker currents than on the healthy side; with comparatively very small currents, we see An.Cs., and especially Ka.Cl.Te).*

Reversal of the Contraction Law

These quantitative disturbances are accompanied by a second qualitative element of change. The galvanic muscular contraction has lost the normal, lightning-like character. It has become tardy ("worm-like"). It begins slowly and ends slowly. It often happens, too, in this stage that the Ka. closure is not, as in the normal contraction forms, the first stimulation element, which is followed by contraction, but that the An.Cl.C., or the An.O.C., appears with weaker currents. This symp-

*Those cases of paralyses in which with stimulation on the healthy side we get muscle contractions on the diseased side are explained by increased excitability of degenerating muscles, especially in the facial. Probably there are current streamers that act more strongly and quickly on them, because of increased excitability of the diseased muscles, than the current closely applied at the exciting-point does on the healthy muscles. Off and on, however (especially on the chin and lip muscles in facial paralysis acquired in early youth), this phenomenon is to be traced to the fact that bundles of healthy muscles extend over to the diseased side. Isolated cases in which the excitability is not at all increased, but decreased, and in which stimulation of healthy muscles is followed by reaction of the symmetrical diseased ones remain unexplained. (It may be that this is connected with the above-mentioned formation of "virtual" poles.) Likewise unexplained are the appearances of reflex contraction in the healthy facial muscles with stimulation in the region of the diseased muscles, as seen in facial paralyses of all kinds, particularly often in central lesions (Bernhardt). Concerning reflex contraction compare also Chapter III., page 50.

tom, which we designate the reversal of the contraction law, is, however, not constant. It is not an absolute requirement for the diagnosis of D. R.

The chief characteristic of the D. R. that is pathognomonic for it and to be depended upon is the tardy contraction.

It is a frequent occurrence that the most excitable point of the degenerated muscle changes its position. The excitability is no longer greatest at the point of nerve entrance, but farther toward one of the muscle ends. In this fact of the increased excitability of the end parts of the degenerated muscle lies the explanation of the above-mentioned occurrence—the reversal of the contraction law, according to Wiener's remarkable experiments. According to Wiener, this phenomenon rests on the stimulation of the excitable muscle ends by the so-called "virtual kathodes," which appear at these points as soon as the An., as exciting electrode, is applied on the middle part of the muscle. With the negative exciting electrode, on the other hand, the end parts of the muscle are reached by the slightly effectual "virtual anodes." With normal muscles the excitation-point and the most excitable point coincide in the middle of the muscle. Thus with An. stimulation the virtual kathodes, which appear at the muscle end, find relatively few excitable points. The reaction there is usually a reversed one. Only, as Wiener has found from positive physical grounds, the penniform muscles often normally show a reversal of the contraction formula (*e.g.*, at the interossii of the hand), and at the deltoid this can frequently be proved. Moreover, by virtual poles we understand those supposed points in the interior of the body at which the current conducted to a nerve or muscle leaves it again.

Virtual Poles

Usually we find also that in this stage the mechanical muscle excitability (*e.g.*, tired through striking with the percussion-hammer) is increased, and moreover that this contraction takes place tardily.

Whereas, in slight attacks, this stage of the "crisis" lasts about two to five weeks, in more severe forms it takes much longer, about fifteen to twenty or thirty weeks, before the electrical current shows a change in the sense of a recovery or muscle destruction.*

The numbers given are only approximate, as, of course, are all the numbers in the table. Often forty weeks, even a year or more, pass without a possibility of proving any real tendency to change in the diseased region, either electrically or functionally. And still, despite this long time, the reaction may return to the normal. In many cases there begins only then:

Stage of Regeneration

Stage III. Stage of the regeneration. There appears, in rare cases about the fifth to the eighth week, generally about the fifteenth to the thirtieth, a gradual return of the indirect (nerve) excitability for both kinds of current; also the "faradic muscular" (that is, the faradic direct) excitability returns again—in the beginning only for strong currents, later for the same current strength as on the healthy side. At first muscle contractions appear in one or two muscles, gradually in more, with indirect stimulation (with one or both currents), or with the direct faradic stimulation. And at about the same time the galvanic muscle excitability, which before showed an abnormal increase, sinks to the normal, or often below the normal. At the same time

* These latter, the moderate cases of the D. R., which show the first tendency to recovery after fifteen to twenty weeks, are very much more frequent than the slight cases that generally run their course in six to eight or twelve weeks.

—and this is practically important—the form of the contraction loses its tardy character. At first it has an undecided appearance. It is no longer "worm-like," tho still distinctly slower than normally; then gradually it wholly loses its tardy character, and at last becomes again "lightning-like." If the "reversal of the contraction law" has been present this also becomes rectified—An. contractions = Ka. Cl. C. until finally the Ka. Cl. C. again preponderates.

Normal Stage

Stage IV. Finally all has become normal, only the excitability (particularly the muscular) generally remains diminished for some time, subnormal, without, however, any other qualitative abnormality.

Subdivision II.—Severe Complete D. R.

Severe Complete D. R.

In the cases in which the lesion is of such a nature that recovery can not take place (*e.g.*, in severings of the continuity of the nerves that remain permanent), the electrical investigation presents the same picture as in the slight and moderate cases.

Stages I. and II. run their course in the same manner as with the curable cases. Toward the end of the first week decrease of the indirect as well as of the direct excitability for both kinds of current occurs; in the next weeks there occur entire extinction of nerve excitability for both currents, and extinction of the direct muscle excitability, even for the strongest faradic current, while the galvanic muscular reaction shows the typical picture of the D. R.—increased excitability, tardy contraction,

etc. But instead of the stage of regeneration now comes:

Stage III. The stage of absolute muscle destruction. The indirect excitability from the nerve continues extinguished, as well as the direct faradic muscle excitability. The increased galvano-muscular excitability sinks as with the curable cases, but it sinks far below the normal, and the contraction does not become quicker, but remains tardy. Sometimes it even seems to become more tardy and dragging with time. The contraction formula, also changed, shows no tendency to return to the normal. Finally, a quite worm-like (anodal) contraction can be obtained with very strong currents; at last this also disappears. The muscle-tissue is destroyed, and connective tissue has taken the place of the contractile substance.

Absolute Muscle Destruction

Subdivision III.—Partial D. R.

The partial D. R. presents, as it were, a sketch of the above-described typical picture of complete D. R.

Partial D. R.

Stage I. This is generally quite like the complete. In it we find diminution of the excitability for both kinds of current, with direct as well as with indirect stimulation, toward the end of the first week. Occasionally increased or normal excitability also exists.

Stage II. In the following weeks, however, there occurs no extinction of the excitability; but the excitability of the nerve, as well as the faradic excitability, is retained; they merely show diminution more or less strong. Frequently they remain also entirely normal.

On the other hand, the galvano-muscular reaction shows all the characteristics of the D.-R.—tardy contraction and increased excitability (eventually reversal of the contraction law).

Stage III. After a few weeks—generally from eight to twelve—all becomes rectified and returns to the normal.

But the partial D. R. sometimes takes an entirely different and not so favorable course. It may often be demonstrated in progressive disease, *e.g.*, the spinal myatrophies, syringomyelia, etc., and particularly in diseases in the region of the central cells of the peripheral motor neurons.

The Severe Form of Partial D. R.

At first the same electrical conditions, as were just noted, appear here. But the diminution of the indirect and direct faradic excitability remains very long, for months and even years; and excitability continues to sink, but does not reach extinction. During this time also the galvano-muscular excitability, at first increased, sinks to the normal, often far below the normal, while the contraction retains its tardy character. This condition may remain, or there follows after years an extinction of the excitability on the whole line—of the direct as well as the indirect, for both kinds of current.

In the slowly progressing spinal myatrophies (also with other spinal disease) we find three forms of electrical changes particularly frequent:

(1) Simple, quantitative diminution of excitability (see page 109) for both kinds of current (direct as well as indirect), progressing to extinction.

(2) Complete D. R. (the severe form); or, most frequently,

(3) The just described form (which we may call the "malignant" form) of partial D. R.

The first and third forms are distinguished in appearance and course only by the fact that, with the "malignant" partial D. R., the galvano-muscular contraction is more or less tardy, while in the simple progressive diminution it remains lightning-like.

The search for one of the different forms of D. R. and the discovery of the present stage of the same has (1) a local diagnostic, (2) a prognostic, occasionally also (3) a therapeutic value. That which is worth mentioning in relation to local diagnosis has already been sufficiently discussed above. D. R. shows (for exceptions see page 138) an involvement of the peripheral motor neurons. At what point in these neurons the disease is located further investigations—that of the mobility, the sensibility, the reflexes, the history—must show. Lack of D. R., to be sure, proves nothing against an affection of the peripheral nerve-units. Only in such cases its presence is by far most frequent.

The Usefulness of the Scheme

After what has been said and with the help of the tables, we can usually decide without difficulty as to the stage of a disease, as to the intensity of the D. R., and accordingly as to the duration and prognosis of the individual case.

The Importance of Differential Diagnosis

For instance, if a patient with a rheumatic facial paralysis is examined by the physician three days after the lesion appeared, and the electrical investigation shows no deviation from the normal, then the patient should be asked to come again after three or four days. If on the seventh or eighth day of the disease there is still no change, then it is very probable that complete D. R. will

not occur. It is possible that either partial D. R. or simple quantitative diminution of the excitability may still develop, or the normal condition continue. It is otherwise if at this time (that is, at the end of the first or the beginning of the second week of the disease) diminution of direct or indirect excitability, or of both, appears. Even then it is still possible that it will go no farther than purely quantitative diminution, or that it may be a question of the beginning of partial or complete D. R.

Determination of D. R.

This can be determined with certainty usually in the second, or at the latest in the third week after the lesion has occurred; if at this time tardy contraction appears anywhere in the muscle, with galvanic stimulation, then the presence of D. R. is positive. In the examination particular attention should be given to the *form of galvano-muscular contraction.* Usually there will then occur also at the same time increase of the galvano-muscular excitability (often also a reversal of the contraction formula).

And at the same time, or a little later, it can be determined if the D. R. is partial or complete. If the nerve excitability and the faradic muscle excitability disappear, then we have to deal with complete D. R.; if it does not disappear, then with partial D. R. It is immaterial whether the excitability is normal, diminished, or increased. In the last case the duration of the disease will not be longer than from six to twelve weeks; with extinguished indirect and faradic muscle excitability the disease (the rare cases of slight complete D. R. excepted), will endure, as a rule, from six months to a year, but may remain incurable.

This last, very important, prognostically significant differental diagnosis—namely, that between the moderate and the severe forms of D. R.—usually can be made not at this time, but only later, generally only after the eighth to tenth, often after the fifteenth to twentieth week. If at this time a return of excitability is found at any of those places where it has been lost—*e.g.*, if we again see a contraction with strong currents after indirect (nerve) stimulation in any one of the muscles of the diseased region, or if a muscle up to this time unexcitable reacts directly to the faradic current—even tho only with greater current strengths—it is a sign that the case is probably curable. The more muscles that directly or indirectly become excitable, the more favorable is the prognosis. If, however, none of this follows, then is it of importance to notice the form of the galvanic muscle contraction; for if the galvano-muscular excitability sinks, and the formerly tardy contraction becomes more rapid, then the prognosis is in general favorable (see Table, Stage III., of the moderate complete D. R.). But if, on the other hand, the galvano-muscular excitability decreases, and the contraction remains tardy, or even grows more tardy, then the prognosis is in general unfavorable. Then it is a case of the severe form of complete D. R. (see Table, Stage III. of the severe D. R.). Of course, one should wait a long time before making an unfavorable prognosis. After thirty and forty weeks, or even after a year, we may see a return of the excitability and a return to the normal galvano-muscular reaction. Prognostic Sign

We shall not give any further examples, but call attention to these practically important facts:

Special Prognostic Significance

1. The D. R. has a special prognostic significance in several forms of peripheral paralyses. They are the so-called rheumatic facial paralyses and certain pressure paralyses, *e.g.*, the radial relaxing paralysis, occurring during sleep, etc. Paralyses of this sort are in the majority of cases curable, and we can distinguish three groups of them:

(*a*) Paralyses without D. R., curable usually in from two to three weeks.

(*b*) Paralyses with partial D. R., curable in from about six to twelve weeks.

(*c*) Paralyses with complete D. R. (we have to deal here usually with the moderate form), curable usually in from six to nine or twelve months.

In all such cases we can generally give the patient his prognosis at the end of the first week, or in the second week; if at this time we find a normal electrical condition, then we have to deal with a case in group (*a*) which is cured usually in from two to three weeks. If at this time we can prove partial D. R., then the disease will usually end after eight weeks. If, on the other hand, the indirect excitability and the direct faradic are extinguished, D. R. occurring at the same time with galvano-muscular excitability, then at least from six to nine months must pass before a cure can be effected, if even in this prognostically favorable case it can be effected at all.

2. While most cases of spinal and bulbar (especially

progressive) diseases, as well as traumatic and rheumatic lesions of peripheral nerves, can be classified under one of the types given above (and while the electro-diagnostic tracing of the changes present may furnish valuable aids in diagnosis and prognosis), still in certain forms of disease (especially in many neuritides, secondary, toxic, or infectious, and in the various meningitides, etc.), the table very often leaves us in the lurch. To be sure, it may be used in these cases *cum grano salis*, and particularly the prognostic difference between the complete and partial forms of D. R. can, as a rule, be shown here. But in their course these cases offer so many irregularities, which depend in part upon external accidents (continued action or temporary cessations of toxic influences, etc.), that real types for the course of these diseases can not be set up. (In regard to lead paralysis, see page 117, in fine print.)

Deviation from the Scheme

3. In paralyses the loss or the disturbance of the active muscle mobility through the impulse of the will is as little synchronous with the electrical changes as is the eventual return of this mobility. In one case paralyses appear first, and the electrical changes follow —for instance, in most cases of traumatic paralyses loss of motion appears immediately after injury, but D. R. appears only after a number of days—and at another time an electrical change foretells a long time in advance the beginning of paralysis or paresis in a muscle otherwise apparently intact (*e.g.*, in progressive spinal paralysis, in lead paralysis, etc.). In such cases the electrical discovery is naturally of particular significance. In dis-

The Active Mobility

eases which are capable of regeneration the voluntary innervation usually returns earlier than the reaction to the electrical stimulation. Still there are numerous exceptions to this.

Partial Paralysis

4. In many cases the muscles in the region of the paralyzed nerve are not all affected by the paralysis, or not all in the same degree. Accordingly, the various muscles act quite differently under electrical stimulation. This is easily comprehended if we think of a myogenic disease which creeps, as it were, from muscle to muscle, or if we think of a disease which affects the muscle directly, *e.g.*, a trauma. (As discussed above, page 109, the electrical changes in such cases will usually be of a purely quantitative nature.) The occurrence of partial paralysis would be more difficult to understand if it were a question of a disease of the peripheral nerves or of the central organ.

The following anatomical data will facilitate the understanding of these facts:

The Localization in the Spinal Cord

(*a*) The spinal anterior horn motor cells from which the motor impulses are conducted to any particular muscle of the body do not lie at a single level in the spinal cord; on the contrary, the central-cell representation of a single muscle is often distributed through an entire series of transverse segments.

(*b*) On the other hand, several different muscles are often represented by cells on the same level.

The accompanying schematic figure (Fig. 27) will explain the conclusions resulting from these facts. Let us take as an example the nerve *X*. We see from the schematic drawing that this nerve receives its filaments from three levels: Levels I., II., and III. Level I. first sends filaments to a muscle *A*, which receives filaments from

nowhere else, and, secondly, a filament to a muscle *B*, which receives the greater number of its filaments from Levels II. and III. Level II. sends besides a filament to the muscle *C*, which also receives a filament from Level III. Now let us assume that a central disease destroys Level I. on one side; then the muscle *A* must degenerate completely, since all the cells and fibers supplying it will degenerate. The muscle *B* will likewise be injured, but so little that, as the mass

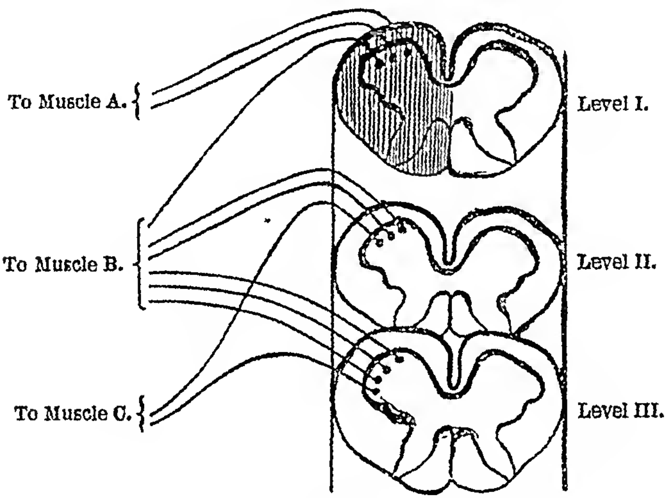


FIG. 27.—Diagram of Spinal Cord Localization.

of its filaments is received from elsewhere, either no real loss of fibers could be proved functionally or electrically or the changes would be only of a slight nature. The muscle *C* would remain entirely intact. If in such cases we should stimulate electrically the trunk of the nerve *X*, we would, indeed, get muscle contraction in the region supplied by it from both kinds of currents; but not all the muscles would contract, only muscles *B* and *C*, while with the muscle *A* no contraction would occur. If we now stimulate the separate muscles directly, we should find muscle *A* faradically inexcitable and showing galvano-muscular D. R. In muscle *B* we should find either an entirely normal condition or slight quantitative diminution of excitability or diminished faradic excitability with galvano-muscular D. R. (partial D. R.). The muscle *C* would show

no kind of change. We should thus have three muscles in the region of the nerve *X;* of these the one, muscle *A,* would show complete D. R. (it is indirectly and faradically directly unexcitable and has galvano-muscular D. R.). Another, muscle *B,* would show a normal condition or simply diminution of or partial D. R. The third, muscle *C,* would show a normal condition.

Difference of Reactions in Partial Paralyses

Such partial paralyses of a nerve region, in which the individual muscles supplied from this nerve show an entirely different nutritive, functional, and electrical condition, are extraordinarily frequent. We find them particularly in diseases which affect the central cells or peripheral motor neurons—that is, in spinal (or also in bulbar) affections; *e.g.*, in acute poliomyelitis of children it is a very common occurrence that with the "leg type" of this disease, in which the peroneus region is most severely affected, the tibialis anticus muscle shows complete D. R., while the other muscles show only a more or less slight injury or remain entirely intact. *Mutatis mutandis,* this is true in many other cases of spinal disease.

But also in injuries or other diseases of the peripheral nerve filaments it often happens that not all the filaments of a nerve become diseased in the same manner, altho with the relatively small transverse area of the nerve-trunk a partial involvement of the same must be more serious than a partial affection of the locally widely distributed (central) cells in the anterior horn. In the fiber affections, the toxic paralyses especially, the disease selects certain muscles, as it were, of a particular nerve region; *e.g.*, in lead paralysis only single

muscles of the radial region become diseased, as a rule. The extensors and the long abductor of the thumb, as well as the supinators (sometimes also the extensor carpi ulnaris), as a rule, are not affected by the paralysis. In these cases we will, to be sure, get a contraction from the radial nerve with electrical stimulation, contractions of some but not of all the muscles supplied by the radial nerve, and in these indirectly inexcitable muscles we will find different electrical changes, at one time stronger, at another time slighter. These partial paralyses with D. R. (complete or partial) of one or several muscles in the diseased region the beginner must not confuse with partial D. R.

The same electrical changes that are found in lead paralysis and other toxic paralyses occur also in peripheral fiber diseases, *e.g.*, in rheumatic and traumatic affections.*

Different Reactions in Same Nerve Region

Frequently, to be sure, if we see a different electrical reaction in different muscles of a diseased nerve region (*e.g.*, in some complete, in others partial D. R.), this is a sign of beginning regeneration. In this stage a return of the formerly extinguished excitability is the rule; and this return usually takes place by one group of fibers recovering after another. Often, however, there is a partial, more or less entire, escaping of individual muscles present from the very beginning in fiber diseases of this kind, to which escape an analogous electric reaction corresponds.

* They are found particularly often in congenital facial paralyses, or in those acquired in early childhood (see page 113).

It appears from what has been said that it is necessary for every investigator, particularly for the beginner, in every electrical examination: (1) to investigate directly, if possible, all muscles of the diseased region; (2) in indirect stimulation (from the nerve) always to observe whether all the muscles supplied by this nerve contract, or if some do not respond. The latter case we may recognize in many instances if the contours of the muscles stimulated fail to spring into relief, or by the absence of a particular muscle function from the combined action which follows from the nerve stimulation.*

Appendix to D. R.

There are still several phenomena to be mentioned that are occasionally observed in the D. R., without, however, having any claim to particular diagnostic or prognostic significance. They must be named simply because in many cases they might appear strange and puzzling.

So far we have spoken of tardy contraction as a sign of D. R. only with direct muscle stimulation, and by stimulation with the galvanic current.

*Thus, to keep to the above example in a degeneration of the tibialis anticus muscle which follows acute anterior poliomyelitis, electrical stimulation of the peroneal nerve is followed by contraction of the peroneus muscle. But, first, the contour of the tibialis anticus does not spring into relief, and secondly, the dorsal straight upward flexion of the foot, which after peroneal stimulation normally follows, in this case occurs outward and upward: only the outer border of the foot will be lifted, and not the inner, from which we may easily conclude that the lifter of the inner border of the foot—that is, the tibialis anticus—fails to respond.

1. But there are cases in which indirect galvanic stimulation shows tardy contraction. These naturally can only be cases of partial D. R.*

Such cases of partial D. R., with indirect tardy contraction, occur frequently in peripheral fiber diseases. **Indirect Tardy Contraction**

We must, however, be sparing of the diagnosis "indirect contraction tardiness." If, for example, the nerve-trunk is very near the muscles supplied by it, as in the facial nerve, when examining for the nerve excitability a seeming indirect tardy contraction may be produced by current streamers in the very excitable muscles (in Stage II.) despite complete inexcitability of the nerve; only if the nerve is far distant from the muscle which contracts tardily with indirect stimulation (*e.g.*, the extensor digitorum communis brevis from the peroneal nerve), may the observed tardiness of contraction be simply described as real indirect tardiness. In other cases, control trials are necessary. (See also page 121, footnote.)

(2) Occasionally also faradic tardy contractions are observed in degenerated muscles. Faradic tetanus does not begin then, as normally, with a jerk, nor does it end, as in the normal, immediately with the current opening, but—just as with the galvanic D. R.—the tetanic contraction creeps in slowly and the contracted muscle again relaxes slowly. This has been described as faradic D. R. Its similarity to the galvanic consists in that the faradic excitability also may be increased in such cases. The cases are infrequent, but undoubtedly do occur. **Faradic D. R.**

* Either of the partial D. R. *sensu strictiori*, or of that stage of complete D. R. which resembles the partial—that is, the initial or the regeneration stage. These stages of complete D. R. we also occasionally designate as "partial D. R."

Here, too, we must beware of confusion; for with muscles that are contracted voluntarily or involuntarily (*e.g.*, through contracture), a seeming tardy faradic contraction is often produced from the fact that the rigid muscle yields only gradually to the electrical stimulation with the slow relaxing of the tension. This faradic "pseudo-" contraction tardiness has nothing to do with the just mentioned so-called faradic D. R. The beginner must simply understand that tardy faradic contractions are not frequent.

Obligatory Contraction Tardiness

If, besides the galvano-muscular, there exists also indirect and faradic contraction tardiness, then we speak of "obligatory contraction tardiness."

Exceptions to the Law of D. R.

In the conclusion of this chapter we shall recur to something which has already been touched upon before, namely, exceptions to the law of the D. R. On page 110 it was mentioned that D. R. has been found in some cases of myopathic muscular atrophy—that is, in a disease whose seat is supposed to be outside of the peripheral motor neurons in the muscles. Likewise in cases of disease of the central motor neuron (namely, in cerebral hemiplegias) D. R. was observed here and there in the paralyzed muscles. It might seem from this that the "law of D. R." (see page 103) does not hold without exceptions; as a matter of fact, this conclusion has not as yet been drawn. Those cases of dystrophy with D. R. have, on the contrary, rather led to the conjecture that dystrophies are all or in part not of muscular genesis, but rather owe their origin to spinal (anterior horn) disease; and for those hemiplegias that occur with D. R. a "secondary associated disease of the anterior horn" is assumed, to which the appearance of degeneration should be attributed. Whether these expla-

nations are correct, or whether later other conclusions may be drawn from these highly interesting cases, can not be determined at present. But this remains certain—and especially the beginner should hold fast to it in spite of the cases mentioned—that they are only exceptions, very infrequent exceptions, and that for the overwhelming majority of cases the D. R. constitutes a positive, almost infallible local diagnostic sign in the sense above given.

Other Quantitative-Qualitative Changes.

In many cases of muscle atrophy, independently of the fact whether they are degenerative or simple atrophy, certain changes in the electrical excitability occur which are composed partly of quantitative and partly of qualitative factors, and which, altho they are not important, are best discussed in connection with D. R. These changes, which do not permit of a local diagnostic conclusion, as should be especially emphasized, but only indicate a presence of muscle weakness, are:

The Diminution of the Maximal Contraction

1. The diminution of the maximal contraction and the contraction in bundles. Until now we have always used its minimal contraction for the determination of the excitability of a muscle, and compared the current-strength with which this occurred with that which caused contraction of a symmetrical muscle or the corresponding muscle in healthy persons. But it is of interest to note how the contraction of the muscle suspected of atrophy takes place. Beginning with a minimal degree of strength, we gradually increase the current, permitting it to become ever stronger. We see then in normal

muscles that the faradic contraction—the faradic tetany—gradually becomes more intense up to a certain limit beyond which an increase of the contraction does not occur; and that the galvanic contraction (Ka.Cl.C.) gradually changes to tetany, which again gradually becomes stronger, till it reaches its limit. The same is noticed in atrophied and in degenerating muscles—*mutatis mutandis*. There are, however, cases in which even with the strongest current the muscle contraction hardly exceeds the minimal contraction; it contracts no more with strong currents than with weak. This is a sign of weakness of the muscles. This may be practically of interest if there is, in the judgment of the physician, simulated muscle weakness, or if this weakness is found in cases of progressive atrophy in muscles functionally still intact.

Bundle-like Contraction

With this reaction-anomaly of quantitative nature, there is often joined one of qualitative, the bundle-like contraction. The muscle in question, being stimulated, contracts not *in toto*, nor even to a considerable extent, as happens normally. Only a few bundles draw themselves together, which then appear as a narrow, slightly prominent ridge. This bundle-like contraction must not be associated with the decreased maximal contraction. Both abnormalities occur separately, and both abnormalities—separate or together—may be united with one of the forms of D. R. From the two named disturbances in themselves no conclusion as to the kind of atrophy present can be drawn.

2. The myoclonic contractions. The same is true of

these as of the exceptions mentioned; they, too, prove nothing but a presence of weakness or of atrophy; they have no local diagnostic significance and occur in association with other anomalies (particularly often with bundle-like contraction). They consist in this, that the faradic current causes no tetany, but only several single, rather clonic contractions of the muscle-substance, which follow each other more or less rapidly during the current closure.* Myoclonic Contractions

If one of these changes has been found, it is well to include in the report an adequate descriptive remark, thus:

	Right.		Left.	
	Faradic.	Galvanic.	Faradic.	Galvanic.
Anterior portion of the deltoid muscle.	100 mm. coil distance (diminished maximal contraction, bundle-like and myoclonic).		100 mm. coil distance (normal).	

(c) *The Purely Qualitative Changes.*

The purely qualitative changes in the reaction of the muscle and motor nerve are rare and may be discussed briefly. At present there are known:

1. The myotonic reaction. In myotonia congenita (Thomsen's disease), the main symptom of which, as is well known, consists in that in voluntary inten- Myotonic Reaction

* Do not confound with this the fibrillary muscle contraction, which is to be seen in normal muscles for a time after current opening if they have been subjected to lengthy faradic stimulation.

tional muscle contraction the contraction outlasts the voluntary stimulation—the muscle contraction continues longer than it intended to. We find that a corresponding lingering of the contraction takes place, as well with mechanical as with electrical stimulation. If we strike a myotonic muscle, the muscle bulge stimulated by striking springs into relief *in toto*, and remains so for a long time. The same occurs with faradic stimulation a long time after the current is opened, and when the electrode is removed we see the contracting muscle standing out hard, rigid, and in sharp relief. Quite gradually the contraction subsides. It is well to distinguish this from the "tardy contraction" of D. R. The myotonic contraction begins with a jerk; the tardy contraction creeps in very gradually; the myotonic contraction occurs as well with the faradic as with the galvanic closing stimulation (generally more decidedly with faradic). The tardy contraction almost always occurs only with galvanic (in exceptional cases with faradic) stimulation; the tardy contraction also does not last so long by far as the myotonic in the cases mentioned. Any one who has seen it once will recognize it immediately and will never confuse it with the myotonic.

We see this change, which seems pathognomonic for myotonia,* particularly with direct muscle stimulation, less often with nerve stimulation. At the same time the quantitative conditions are normal; only off and on is the galvanic excitability increased.

Erb's Waves

In the same disease we occasionally find Erb's waves,

* It seems to occur also in cases of so-called myotonia acquisita.

a further qualitative abnormality. If we conduct a rather strong galvanic current through the myotonic muscle and allow the electrodes to remain after the current is closed, we see wave-like movements in the diseased muscle, that proceed from the Ka. over the muscle-belly to the An.

A kind of counterpart to the myotonic reaction is:

The Myasthenic Reaction

2. The myasthenic reaction (Jolly), probably pathognomonic for myasthenia gravis pseudoparalytica (or

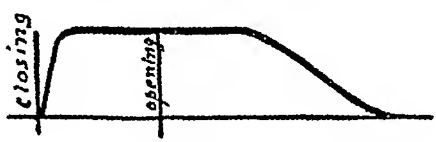


FIG. 28.

asthenic paralysis). The principal symptom of this disease is that of fatigue. A voluntary movement, repeated several times, is performed more and more imperfectly, and, finally, can not be made at all. Such exhaustion is also demonstrated by electrical stimulation. If we stimulate a myasthenic muscle with the faradic current, after it has rested, there occurs at the first stimulation a normal tetany; but with each following stimulation the tetany will be shorter and less intense, and finally, after several successive stimulations, the muscle becomes inexcitable. After a short rest this may be repeated again. This reaction does not occur in all cases of myasthenia, and may in the course of one and the same case disappear and reappear off and on. The same holds for the myotonic reaction.

3. The neurotonic reaction. E. Remak and Marina

The Neurotonic Reaction

have each observed a change of electrical excitability in one case (Remak with a degeneration, probably progressive spinal atrophy; Marina in a case of hysteria) which was distinguished (1) by lingering of the contraction duration analogous to that described in myotonia, but with the difference that this phenomenon was observed, not with muscle stimulation, but with only nerve stimulation (faradic and galvanic), and (2) by the early appearance of the An.O.C. as well as the Ka.Cl.Te., and also the easy production of An.O.Te. What significance these reactions have can not as yet be determined.

CHAPTER V

THE ELECTRICAL INVESTIGATION OF THE SENSORY ORGANS AND OF ELECTRICAL SENSIBILITY

The Electrical Law of Sound and Flash of Light

ANALOGICALLY to the contraction law developed above (page 34 *ff.*) for the motor apparatus (the motor nerves and the muscles), which says essentially that this motor apparatus reacts most easily to the Ka.Cl., with more difficulty to the An.O. and An.Cl., and with most difficulty to the Ka.O., Brenner, Remak, and others have succeeded in proving that the sensory apparatus—namely, the higher sensory organs, eye and ear—also respond in a regular manner to the various excitation elements: most easily to the Ka.Cl.; with greater difficulty to the An.O.; with most difficulty, sometimes not at all, to the Ka.O. and An.Cl. The reaction in these organs occurs (but not always in all persons) if we apply an indifferent electrode to any place (say, on the sternum), as in the muscle stimulation, and an exciting electrode of small diameter directly on the eye or ear, and then change the exciting electrode by means of the current-reverser, first to An. then to Ka., employ different current-strengths and make openings and closures of the galvanic current.

The reaction shows itself in the case of the eye as a

flash of light (usually colored), in the ear as a sound. Thus we can establish a law for the flash of light in the eye and for the sound in the ear, just as we have established a law for muscular contraction. The Ka.Cl.S. (sound) and the Ka.Cl.F. (flash) occur normally with the weakest currents.

The same discovery has been made for smell and taste.

While the muscle contraction law has a significance, tho not a very great one, in certain pathological conditions (see the "reversal of the contraction law" in the chapter "Reaction of Degeneration"), the expectations entertained at first that the same would hold true of the sound and the flash law have not as yet been realized. To be sure, there are cases in which deviation from this law occurs, but there is hardly a case in which the deviation makes a diagnosis or prognosis possible or assists them in any way. Therefore, scientifically interesting as they are, these matters will not be discussed here, since they are a matter of indifference for the practitioner.

Electrical Law of Cutaneous Sensibility

It is otherwise with the electrical investigation of the skin sensibility. This investigation, the practical application of which can not be denied, is quite different from those mentioned before; it tests the reaction of the skin, not with the galvanic,* but with the induction-current, and it is not a qualitative investigation, as in the eye and ear (in which, perhaps, the stimulative effect of the different current manipulations should be taken into consideration); it is rather a question of a purely qualitative factor. With the application to the skin of the faradic

* Bernhardt has also experimented with galvanic tests.

current with a certain current-strength, normally there occurs a sensation, comparable to ants creeping over the skin, which increases to a painful degree with the gradual strengthening of the current. Consequently, we are able to determine a minimal sensation for the faradic current, just as we can a minimal muscle contraction. This sensation may change under pathological conditions (diminution, increase, or extinction).

The Farado-Cutaneous Sensibility

The sensibility of the skin for the faradic current—the farado-cutaneous sensibility—is of a peculiar kind. How far it is identical with one of the other qualities, and by what path it is conducted, can not be decided at present. In any case it must not be identified with the sensation of pain produced by the faradic current. Only beyond a certain strength does electrical, as well as all other stimulation, become painful.

We try the farado-cutaneous skin sensibility in the following manner: The patient sits with his back toward the apparatus. A large, indifferent, well-moistened plate-electrode is applied somewhere in the middle line of the body. At that point on the body where the electro-cutaneous sensibility is to be tested an uncovered electrode of small diameter is placed.

We use an uncovered, unmoistened, metal electrode, because with such a one the skin resistance is not overcome; thus only a few current streamers enter into the deep-lying tissues, and the surface of the skin, which is the thing we are investigating, is reached by a great concentration of the current, almost the whole of it. Particular electrodes have been constructed for the use of sensibility investigation; the most familiar is Erb's "sensibility electrode"

(Fig. 29) whose flat metal surface looks like a transverse section of a bundle of several hundred thin wires. We may, however, in case of necessity use an ordinary brush or pencil electrode.

FIG. 29.

Procedure in Investigation of Cutaneous Sensibility

Allowing the electrode to remain stationary on the point to be examined, and turning on the faradic current, beginning at the greatest possible coil distance (thus employing the weakest current), we push the secondary coil of the induction-apparatus very slowly over the primary, having instructed the patient to say "Now" at the moment when he feels the first slight crawling at the investigated point. We must call the attention of the patient to the fact that the test depends, not on his feeling a pain from the current, but on his telling if he has a *slight sensation. This precaution is often overlooked*, and, therefore, false results are obtained.

We note the coil distance with which the minimal sensation occurs, and we mark the investigated point of the body with a colored pencil. Then, perhaps after a pause, we repeat the experiment once or twice in the same manner and compare the separate results. Then we proceed in a similar manner with the corresponding point on the other side of the body. The results on both sides correspond almost exactly in a normal condition—at least to a few mm. C. D. (coil distance).

In pathological cases of one-sided sensation-anomalies we have in the difference of coil distance between the

symmetrical points of both sides a computable measure for the disturbance of sensibility present. In such cases the electro-cutaneous investigation has, first, the advantage of exactness in recording the status; secondly, the greater advantage of being able in the course of a disease process to follow by means of a sensitive test the changes for better or worse in the abnormal sensibility present. For diseases affecting both sides the method is of most value in the second-named sense. We must not, however, forget that the induction-apparatus does not give constantly comparable figures in an absolute measure, as does the galvanic, and that in the course of time it changes considerably by wear and tear.

Farado Cutaneous Sensibility in Damage Cases

The electrical sensibility test often finds a further and useful application which it is well to observe. If a person who is to receive damages because of accident or disablement, or who is to be compensated on the ground of private agreement for an existing disease, declares during examination (as often happens) that he has disturbances of sensibility for any one of the qualities of feeling,* it will be desirable, since the statement of the interested person may be untrue, for the investigator to have an objective control over his subjective statements. The farado-cutaneous testing offers a sort of control, tho not a certain one, in many cases of this kind. A man who is simulating or exaggerating a disease will also at

* Such disturbances particularly are often alleged by people in whom it is a question of some functional nerve disease. The hysterical "one-sided hypesthesia" is well known in the circle of shysters and those advised by them.

times try to deceive during the examination for sensibility, and will acknowledge minimal sensation only with higher current-strengths than is actually necessary. A repeated retesting at the same point on the body (while the person under examination has his back turned to the apparatus) promptly reveals the deception, since the separate statements, especially if there are pauses between, will not tally with each other. To be sure, such an attempt at unmasking can be used only when there are positive results, for in the region of other sensibility qualities there are disturbances in which the faradocutaneous quality has not appreciably suffered, so that indeed one may really have skin sensation-anomalies, and yet show the normal minimal sensation with the faradic apparatus. Rise of the electro-cutaneous sensibility has been found in tetany.

Electro-muscular Sensibility

Finally, it is to be mentioned that, besides the electro-cutaneous, there is the electro-muscular sensibility, which with high current strengths is felt as painful contraction in the muscles. How far this is identical with the feeling of electrically produced muscle contraction will not be discussed here. The fact is, that in pathological cases in in which the faradic muscular excitability is extinguished or greatly diminished (*e.g.*, in peripheral or spinal paralysis), despite the fact that sensibility disturbance can not be proved with the usual methods, much greater current strengths can be borne by patients without pain than in the normal. This is to be traced to the fact that, in every strong faradic stimulation of muscle, the pain is composed of two components: the electro-cutaneous

and the electro-muscular pain. If the muscular pain is lost entirely, or almost entirely, from the fact that a muscle contraction does not take place (*e.g.*, in peripheral paralysis with extinction of the excitability), it is easily understood that stronger currents than in the normal are required to cause pain.

CHAPTER VI

RESISTANCE

ALTHO the test of the resistance (R.) and of its disturbance has for the practitioner only slight significance, still for the sake of completeness its essentials will be discussed in the following.

Resistances As has often been mentioned already, the human body offers resistance to the electrical current. Besides the body, the medical application of the current finds other resistances: the resistance of the cell itself, that of the metallic conducting-parts, and, very particularly in the German apparatus, more or less German-silver resistance of the rheostat, according to the position of the rheostat handle. The greater the resistance which the current encounters on its way from the cell to a muscle, the weaker, *ceteris paribus*, will be the strength of the current which is effective on that muscle (that is, with the same number of cells—the same electromotor force). $C. = \frac{E.}{R.}$; reversed $R. = \frac{E.}{C.}$ (see page 11).

In many cases it is interesting to determine, numerically, how great especially is the body resistance, because under certain physiological and pathological conditions changes of this resistance occur. We have, as already stated above, a unit of measure for the electrical

resistance by means of which we can express it in numbers—namely, the ohm (see page 12).

Now, how shall we reckon the body resistance in a special case? This is done by means of the so-called "substitution method," according to the following very simple direction:

Method for Investigating Resistance

If we moisten two electrodes of a galvanic apparatus and place them with their surfaces in direct contact, then include in the circuit a desired number of galvanic cells (say, *e.g.*, 20), and move the handle of the rheostat (that is, remove so many German-silver rods from the main circuit) until the galvanometer shows the desired number of ma. (*e.g.*, 4 ma.), then this simple computation will follow by means of the Ohmian law: 4 ma. = $\frac{\text{20 cells} - \text{E.}}{\text{R.}}$. Expressed in words this equation is: In order to produce a current-strength of 4 ma., we need a certain fraction of electro-motor force of the included 20 cells with the arrangement mentioned, namely, one large enough to equal the resistances present in the circuit. But these are principally the German-silver resistances of the excluded rheostat contacts. On the rheostat contacts there are numbers, according to which we can read at once, from the rheostat resistance-table accompanying each apparatus, how many ohms of German-silver resistance have been included. *E.g.*, we read from the position of the rheostat that it points to 6. The resistance-table says: "6 = 26,000 ohms." With the rheostat resistance of 26,000 ohms, a current of 4 ma. flows through the well-moistened electrodes from the 20 cells.

Human Body in Circuit

Now, if with the arrangement of the apparatus unchanged, we include some part of the human body in the circuit by applying the electrodes, for example, on both sides of the forearm, we will at oncc see that now the galvanometer needle indicates a smaller current strength, *e.g.*, $1\frac{1}{2}$ ma. C. has become smaller, despite the fact that E. has remained the same. This can be only because R. has increased; the resistance of the body has been added thereto. Now we push the handle of the rheostat forward clockwise; we exclude rheostat resistances until the galvanometer needle again resumes its former position—that is, indicates 4 ma. Now the rheostat handle stands at another contact, *e.g.*, 30; the resistance-table says "30 = 1,090 ohms." Thus, in order to get the same current-strength with the resistance of the body that we had before without it, 26,000 − 1,090 ohms = 24,910 ohms of resistance had to be excluded from the circuit. In this case the body offers this amount of resistance.

Skin Resistance

It has already been said that of all the tissues and organs of the body the skin offers so much the greatest resistance to the current that all other body resistances (and also the resistances of the good conducting-parts of the apparatus), practically need not be considered. This rule goes so far that even the greater or lesser distance between the two electrodes applied to the surface of the body practically plays no part in comparison with the skin resistance directly under the electrode itself (see page 13, footnote). If, then, we wish to determine the resistance of a certain part of the body, we have only to reckon the resistance of the skin of this region. In

order to investigate this local resistance most conveniently, we shall apply both electrodes in this region—as it were, include the region between the two electrodes.*

Sinking of Skin Resistance

Above (see page 14) we have already remarked—and this is of a certain diagnostic and therapeutic significance—that the skin resistance changes while the galvanic current is passing through it. It sinks as the current begins to take effect, so that, by this lowering of the R., after a long current closing with stationary electrodes, the C. gradually becomes greater, as we can see from the galvanometer. This sinking does not continue indefinitely, but after a certain time it reaches the point at which the current-strength (relative constant resistance) † remains constant, as compared with the primary resistance.

Now, if we wish to get comparable results in regard to physiological processes or pathological conditions, we must observe three things in the method of experimenting given above:

Constant Resistance

1. We must always note the constant (final) resistances—that is, we must permit the current of this desired strength (in our example the current of 20 cells) to take effect for a time with the electrodes unchanged, before we reckon the resistance. Hence if, as we assumed, we had cut out so many rheostat resistances at the beginning that the galvanometer needle showed 4 ma.,

* Only we must not place the electrodes so close to each other that their surfaces touch, for then the current will go directly from electrode to electrode without reaching the body.

† We find out the absolute constant resistance by allowing strong currents (5 to 15 ma.) to take thorough effect.

then we wait several minutes; during this time we shall see the needle move gradually of its own accord farther on and indicate $4\frac{1}{2}$, 5, 6 ma., etc. We wait until we see that no further movement of the needle occurs, showing that the current-strength does not increase (*i.e.*, the resistance does not become lower). This point is reached usually after a few minutes. Now we grasp the rheostat handle again, move it back to the point of beginning (4 ma.), and reckon the body resistance by means of the table and in the manner which has been described.

2. We must also always take into consideration the first resistance and the difference between this and the constant.

3. Finally, we must always observe the time that the resistance requires to sink to the constant point.

The Physiology of Resistance

The two latter conditions differ widely with different circumstances. In the aged the primary resistance is very high, but often sinks rapidly and considerably. Different points of the body also behave differently in relation to resistance. It is best during the entire duration of the investigation of resistance to observe, watch in hand, the galvanometer needle, and to note its position every half-minute till the constant point is reached.

Besides this, the following may be noted with reference to physiological points:

The skin resistance is generally lower: (1) At places that are usually covered with clothing. (2) At places with tender skin or with no epidermis (for instance, in mucous membrane) or with no growth of hair. (3) At sweating or moistened places (dry electrodes on

a dry skin offer absolute resistance to the galvanic current).* (4) At points that contain many hair-follicles or gland-ducts.†

The skin resistance can be artificially diminished: (1) By moistening the skin and the electrodes. (2) By soaking the skin and the electrodes with warm or salt water. (3) By current manipulations (particularly current-reversing); and, finally, as said, (4) Through continuous application of the current.

According to what has been said, it appears that no definite numbers can be given for the resistance of the various parts of the body. First resistances of 37,500 ohms, and absolute minimal resistances of 1,300 ohms have been found. Eulenburg has found in the head the average resistances of 1,200 to 1,600 ohms.

Pathologically there are found:

(*a*) Diminutions of R.: (1) In Basedow's disease (rapid reaching of the relative constant); (2) in hysterical anesthesia (Vigouroux); (3) in "traumatic neuroses in the head" (Mann). Variations of R.

(*b*) Increases of R.: (1) in scleroderma (local increase of the relative constant); (2) in myxedema; (3) in elephantiasis and similar affections; (4) in infantile hemiplegia (Vigouroux and Mann).

* Against the faradic current the skin resistance plays so small a part that it may be practically disregarded.

† We must here remember that these places offer entrance, as it were, to the "current-threads."

PART II

ELECTRO-THERAPEUTICS

CHAPTER VII

GENERAL PART

Before the details of the electrical treatment of different diseases and diseased conditions can be discussed, two preliminary questions must be answered: (1) Has electro-therapy any therapeutic value at all? (2) Wherein does this therapeutic value finally lie?

Therapeutic Value of the Current

Some authors and practitioners deny that electrical treatment has any curative effect at all. Approximating this absolutely skeptical attitude, which certainly lacks all justification, there is the view that the efficacy of electrical treatment is due to the psychic factor in it—that is, to suggestion—rather than to any specific therapeutical quality. Well-known nerve specialists share this view.

If this view is correct, then a special method in the application of the current for healing purposes is wholly superfluous. The principal point would be to work on the mind of the patient through the peculiar sensation of the current, through the impression made by the complicated apparatus, by the accomplishing of the most striking effects possible (muscle contraction, flashes of light before the eyes, reddening of the skin, etc.). The same effect might be attained also by any number of other methods. In this case, then, it would become a

matter of secondary importance, if not of absolute indifference, whether the faradic or galvanic current, the An. or the Ka., a larger or smaller electrode, should be chosen.*

The Psychic Effect of the Current

We must emphasize from the beginning the fact that, according to the almost universal experience of experts, a very considerable part of the electro-therapeutic results must be accepted as psychic. The same therapeutic results are often attained from the application of the most various, even apparently opposite, methods; disease symptoms are occasionally removed, when, by mistake, no current has passed through the applied electrode; and there is a whole series of similar and frequent observations that permit of no other explanation than that of psychic causes. It is, however, an incorrect conclusion, if we infer from these facts that electricity works only psychically as a remedy; it will rather be a question for every unprejudiced person whether, besides this acknowledged psychic value, there does not exist another, a specific curative value of the current.

It seems highly improbable from the very beginning that the electrical current which produces such mighty physical and chemical effects outside of the human body, and which has so many important physiological relations to the body itself (especially to the nervous system), should remain entirely without effect on diseases of the body, and especially on those of the nervous system. Numerous physiological experiments have demonstrated

* Even purely suggestive effects are increased by exact methods.

the effects of the electric current on the healthy body (contraction-exciting, vasomotor, refreshing, electrotonic, etc.); such effects, moreover, are not required for curative use by the sick body. The daily practical experience of medical authorities who have recognized certain electro-therapeutic methods as successful, either empirically or supported by certain theoretic considerations, enforces this demonstration; and, in addition, there are certain recent concrete cases wherein the application of the usual current-strengths (without suggestion) has produced a specific healing effect. There are to be mentioned: (1) E. Remak's series of exact clinical experiments in radial paralysis, which by their number prove incontestably that a certain method of treatment shortens the healing period; and (2) experiments on animals, in which the psychic effect does not figure, and in which artificially produced disease (paralysis, R. Friedländer) seemed to be recovered from more rapidly with the application of the electrical current than without the same.

The Specific Effects

To be sure, the unequivocal facts, from which we can exactly determine the specific curative effects of the electrical current in all or even in many separate cases, are at present far too rare. But if this effect has been proved only in a few cases—and it has—that suffices to permit us to reject as insufficient the bare hypothesis of suggestion (sans phrase).

There is then, as we have seen, a specific curative effect of the electric current. But of what does it consist? That is the second question, much more difficult

to answer than the first, because here everything is hypothetical.

Physical Theory

If we take into consideration the nature of electricity and judge by analogy from its other working spheres, the acceptation of a physical effect seems most obvious from the beginning; the effect of influencing the smallest cells of the body (molecules) in the sense of directly accelerating, retarding, or changing the direction of the presumed permanent motion of these particles in the living body. So long, however, as we know so little of the nature and underlying principles of these processes as we do at present, it will naturally be impossible to lay the foundation of a certain method in the attempts at a therapeutic change of these processes. Plausible as this hypothesis is, up to the present it has been of no practical value.

Chemical Theory

It is otherwise with the second theory, founded on the fact of electrolysis (that is, the separation of fluids into their component elements by the electrical current). It tries to trace the curative effects of the electric current chiefly to chemical processes. This theory has found numerous adherents in earlier as well as in later times. Frankenhäuser, Schatzkij, and others have tried to show that, through the influence of the galvanic current, "ions" (that is, the component parts of the molecules liberated by electrolysis) are set free and can move toward the poles, producing metabolic assimilation by chemical changes which have a curative effect in the various tissues of the body, which are regarded as a series of varied, moist conductors.

It has also been proved through numerous experiments that we are able to send into the body, through the unbroken epidermis, certain substances (iodin-salt solutions, cocain, etc.) from the An. (cataphoresis). This fact has been drawn upon as an explanation for the curative effect of electro-therapy. Moreover, according to Schatzkij, this originates exclusively from electrolysis, and is to be considered a result of ion wanderings.*

That generally a chemical process can be produced in the body through the electrical current is to be regarded as certain. However, whether it is possible to get considerable electrolytic effects deep down with the current strengths usually applied to the unbroken skin ("percutaneous"); and if so, whether these effects are curative effects are questions still waiting for proof. The advocates of the chemical theory consequently require the application of high current-strengths, and French therapeutists, Bergonié, Leduc, and others, as well as a number of German authors, Frankenhäuser and others, have lately suggested methods of treatment which require, even on the neck and the head, current-strengths of from 40 to 60 ma. We shall discuss this more fully below.

Physiological Theories

A series of additional theories for the explanation of electro-therapeutic results is based on phenomena that were observed and studied by physiologists. On the one

* The same author also explains by electrolysis the polar effect of the An. in soothing pain, which will be described later on. He claims that through the current acids are conducted to the sensible nerve-ends at the An., and mechanically irritating substances are neutralized by means of the phoresis.

hand we have the fact that the blood-vessels react to the electrical current by contraction and expansion, and this has been made responsible for the curative effects of electrical treatment.* On the other hand, the electrotonic phenomena described on page 36, the decrease of the nerve excitability at the An. (anelectrotonus), and the increase of the same at the Ka. (katelectrotonus), which were found in animals and have been transferred to human beings, have been represented as therapeutically important agents. In the latter theory, according to the older and newer experiments (Leduc), probably pertinent also to human beings in cases of increased nerve excitability (*e.g.*, neuralgias), we must apply the An. therapeutically as the "different electrode." On the other hand, in diseased conditions (*e.g.*, paralysis) in which we wish to increase the excitability, we must chose the Ka. as the "exciting electrode." We call this "polar treatment." Its main principle is the "soothing" effect of the An. and the "refreshing effect" (R. Heidenhain) of the Ka. At the same time it is very much to be questioned whether these effects may be transferred to other than the most peripheral part of the nerve-muscle apparatus, and we should always hesitate somewhat in extending the electrotonic principle to the central organs—a rule which is unfortunately often forgotten.

Polar Treatment

Further, we must not disregard a point which seems

* R. Remak designates the effect on the blood-vessels plus the chemical and cataphoric effect as the "catalytic" effect of the electrical current.

by far not the least essential—namely, that the fact of muscle contraction through electric stimulation makes natural the inference that the current, by bringing about contraction in paralyzed muscles, may exert a favorable influence on the nutritive conditions of these muscles.

A particular therapeutic effect is ascribed to high-frequency currents by d'Arsonval and his pupils (see Chapter XI. "On Teslaization")—namely, the effect of inducing metabolic change and of increasing blood-pressure. Further experiments have shown, however, that these effects are to be traced back to accessory stimulation, and not to the current (Toby Cohn, A. Löwy, and others).

Reflex Effect

Finally, with the close connection of the nerve-cells (neurons) of the body, a reflex effect may doubtless be exerted upon distant parts by electrical skin stimulation, or by influencing muscle sensibility through the medium of the muscle contraction. Thus a change at the stimulated points will affect other parts of the nervous system, *e.g.*, the central organ, in the sense of checking the functions (in neuralgia), or of increasing them by removing obstructions (in hemiplegias); for example, by diverting the attention, stimulation of a point at a distance from the diseased point may produce a curative effect (Goldscheider).

Chemical Effects

If we survey all that has been and is said in explanation of therapeutic results, we must distinguish two things which may be accepted as certain—namely: (1) That, besides the psychic effect, the current causes chemical effects in the body—effects on the blood-vessels and on nerve excitability, as well as muscle contractions—

and (2) that it also produces changes in the molecular life of the tissues.

In regard to which of these effects is to be expected in a particular case and with a special method, and whether the effect will be the desired one, a curative effect, there are unequivocal and undisputed facts in only the rarest cases; so that, in spite of all hypotheses, we have no other resource in methods than empiricism, the experience of critical authors and practitioners and our own. At the same time one or another of the hypotheses given above may occasionally serve as a foundation for special methods. Only in a few cases can the therapeutic indications and contraindications be given with a degree of certainty.

General Rules

The beginner will do well to memorize a certain therapeutic scheme at first, for which the following will give him the points. But he must not forget that a scheme never has general validity, and that it is the therapeutist's right and often his duty to deviate from this scheme —to individualize. This is nowhere more important than in electro-therapeutics. The best therapeutist here will be the one who schematizes least. It is the more to be deplored, therefore, that in many cases, especially in hospitals, electro-therapy is in the hands of the junior assistants or orderlies. The result of such a state of affairs every one knows who has had opportunity to observe it.

Localization of Treatment

The second, really self-evident requisite for the therapeutist is the localization of the treatment at the point of disease. This is, of course, often more easily said than done. For in many cases the seat of the disease

can not be reached directly by the current (as in paralysis of the eye muscles), or it is unknown (as in certain functional neuroses), or, finally, the changes caused by the disease are such that there is no prospect of accomplishing anything by influencing the disease center directly (as in progressive degenerative diseases of the central nervous system). Such cases we must be satisfied to treat symptomatically—that is, at a point distant from the seat of the disease where the principal symptoms are noticed. In general, however, the principle of localization is much to be preferred to that of symptomatic therapy, as will be explained further in the special discussion.

Finally, the dosage of the current may be mentioned as the third important requisite. Here also the views of authors and practitioners differ widely. We have already mentioned above (page 165) that of late, there is, in treating neuralgias, Basedow's disease, headache, etc., an inclination, especially among the adherents of the electro-chemical theory, to use currents as strong as possible (galvanic up to 60 ma.). On the other hand, another extreme point of view is represented by those who would apply the homeopathic principle *"breve, leve, sæpe,"* to electro-therapy. It will be well in the mean time—this is the opinion of the majority—to steer clear of both extremes in practise until further experience has been gained,* and choose current-strengths not too Current dosage

* The cases cited by the authors of these tendencies, said to be cured by their methods with exclusion of suggestion, need further critical proof.

great; but, on the other hand, not to take into practical consideration the absolutely unproved statement, that minimal current doses, applied for fractions of a minute, are "adequate stimulations" for the diseased nervous system.

The rules for special cases will be given in the chapters to follow. In general, the following is to be said concerning the current-strength used and the manner of applying the current, regard being had to galvanization and faradization:

Principles of Dosage and Application

1. Patients like to "feel something" in electrical treatment. With too weak currents they feel nothing and do not believe in their efficacy. Since the suggestive factor plays a not insignificant part in our therapy, we often rob ourselves of an ally if we use too weak, imperceptible currents. For particular reasons we should use such currents only exceptionally; but in many cases—further discussed below—we have to use them.

Strong Galvanic Currents

2. Too strong galvanic currents cause a painful burning of the skin, and especially of the mucous membranes, and they ulcerate the integument so that sometimes, even after a single application, ulcerations of greater or less depth remain. The beginning of pain should be a warning that the current-strength has reached the limit permitted. Only a "slight burning" should result (nothing more) as a rule. The galvanization of mucous membranes had better be omitted altogether. Faradic currents of greater strength merely cause pain and reddening of the skin; there is hardly

any other injury in the current-strengths which we have at command. Only we should not turn on strong faradic currents suddenly, because this frightens patients who are being treated for the first time.

Medium Galvanic Currents

3. Galvanic currents of only medium strength, applied to the head or neck, cause dizziness, dancing before the eyes, a galvanic taste on the tongue, occasional nausea, buzzing in the ear, conditions similar to collapse, hysteria, and screaming fits, or attacks of other kinds. The same things, and in a more extreme measure, may occur when small current-strengths are applied at the head or neck; if at opening or closing the circuit (especially with an electrode of small area) considerable fluctuations of the current take place—that is, if the current is not increased or decreased gradually, but suddenly. Therefore, in treating these parts of the body, we must always use the rheostat and carefully go from contact to contact; forward when we close the circuit, backward when it is opened. We call this "creeping in" and "creeping out." From the way in which the galvanometer needle moves, we know whether this creeping in and out occurs slowly enough. The needle must not swing back and forth, but must move slowly and evenly in the desired direction. It is also well, in order to reach a certain current-strength gradually, to use the whole rheostat if possible—at least a large part of it—and to include as few cells as possible in treating the parts mentioned. Then by means of the rheostat we can avoid any fluctuation more easily than when many cells are used, with which, it is easy to see, the leaps

would be greater, and, in spite of the rheostat, fluctuations could not be avoided.

4. The same thing (namely, the avoidance of current fluctuations from including and excluding) must be observed in polar treatment (see page 166)—that is, if in analogy to examinations on animals we wish to produce the anelectrotonus or katelectrotonus in a live person for therapeutic purposes. For instance, if in neuralgias we wish to apply the anode at the painful point in order to decrease the excitability of the nerve which is causing the pain, we must not turn the current on and off suddenly, but in the way described under 3; for as soon as current fluctuations of any kind occur in the animal, after the circuit has been closed, the so-called negative modification takes place (see page 36)—that is, the katelectrotonus occurs in place of the anelectrotonus, and *vice versa*. If, hypothetically, we carry over the conditions from the animal to man, we must take this fact into consideration.

Current Reversing with Closed Circuit

5. For the reasons mentioned, we must not attempt to reverse the current with the circuit closed in the cases mentioned under 3 and 4, nor to close or open the circuit suddenly. It would be well in cases of this kind to instruct the patient that he must not remove the electrode before the treatment is ended; many do this involuntarily when flashes of light, dizziness, etc., occur. One should also avoid using an interrupter-electrode in such cases, because unintentional openings and closings might easily occur through pressure on the interrupter lever. Therefore for therapeutic purposes we should

also first apply the electrodes, and then slowly turn on the current, and likewise after the close of the treatment first turn off the current (by turning the handle of the rheostat slowly back to 0 and so cutting out cells) before removing the electrodes from the body.

6. Turning the apparatus back to the point of rest (0) before taking off the electrodes is advisable in any case, as it is easily forgotten otherwise, and the cells remain active and are used up unnecessarily (if the electrodes touch each other accidentally in the table-drawer, etc.).*

Necessity of Using Well-Soaked Electrodes

7. If we wish direct effects on deep-lying points (muscles, nerve-trunk, central nervous system, etc.), we should use well-soaked (not merely moistened) covered electrodes, under which skin resistance is lessened. Dry electrodes—especially of metal (brush, pencil, etc.) directly affect the skin and its nerves and only indirectly (reflexly) the central nervous and circulatory systems. They are used specially with the faradic current. It is not advisable to use metal electrodes with the galvanic current because serious ulcerations set in very easily. Therefore we should be careful, in galvanization with moistened, covered electrodes, that the covering is not defective, lest a part of the electrode metal should come in contact with the skin.

Frequency of Treatment

8. Electrical treatment of new cases should take place daily. In long-standing cases a treatment every other day is sufficient. Treatments at longer intervals have at

* There are apparatus with a brake arrangement which automatically remind one of turning off the current.

most only a suggestive value. Likewise electrical treatments which are drawn out through many months and years (which happens often enough) have no other than a suggestive value (except in rare cases). Usually we should change the method, as with every other therapeutic measure, if we see no permanent result after several weeks at most. We must never forget that there are other methods of treatment besides electro-therapy. In regard to the time of single treatments directions will be given in the special part.

9. Feverish patients must not be treated electrically, nor should electro-therapy be used, unless with extreme caution, with the distinctly cachectic (those suffering from cancer, phthisis, tabes, in the last stages), nor with very old people.* Caution or entire suspension of the treatment is commanded in the case of women who are menstruating or pregnant.

For special contraindications for individual cases see the following chapter.

* Althaus's reported "brilliant" results from the electro-therapy of the symptoms of old age may be cited here as a pretty curiosity and as a strong proof of the "autosuggestive" effect of electro-therapy on the electro-therapeutist.

CHAPTER VIII

SPECIAL PART

I. Galvano- and Farado-therapeutics. Methods.

It would be the task of special electro-therapeutics to give exact methods for treating each separate one of the diseases that can be at all reached by electricity. This is not possible with our present knowledge. If we do not wish to lose ourselves in unexplored territory, and if we do not wish without sufficient criticism to exalt to a "method" the isolated experiences of this or that therapeutist—in which it is often difficult to discriminate between the *post hoc* and the *propter hoc*—we must limit our discussion to special methods. Therefore there will here be recommended to the beginner: (1) Only those methods of treatment which are recognized by the great majority of authoritative writers and which are used by the most experienced neurologists in their clinics and in private practise. At the same time it goes without saying that there are almost as many modifications of these methods as there are nerve specialists. In this discussion those procedures will be emphasized which the practitioner can always accomplish easily with simple instructions. As we have said above, and here emphasize again, the facts which will be given are only schemes from which the experienced physician will deviate, indi-

Special Methods

vidualizing in special cases. (2) There are described here with some completeness the therapeutic proceedings for galvanization and faradization only, while the methods for franklinization, teslaization, etc., which are less frequently used and are of little importance to the practical physician (of even less than to the specialist), will be discussed summarily in later chapters. (3) Diseases will be treated in groups as regards their electrical treatment, *e.g.*, diseases of the spinal cord, of the brain, etc. In cases in which special methods have proved useful in certain single diseases this will be emphasized particularly.

We will discuss, then, galvano- and farado-therapy in:

(*a*) Diseases of the peripheral nerves: (*α*) Irritations.
(*β*) Paralysis.

(*b*) Diseases of the muscles.

(*c*) Diseases of the spinal cord.

(*d*) Diseases of the brain.

(*e*) The various functional diseases of the nerves and those of unknown origin.

(*f*) Diseases of the joints.

(*g*) Diseases of the internal organs.

(a) Diseases of the Peripheral Nerves.

Irritations (Neuralgias and Local Spasms).

Neuralgias 1. The local application of the galvanic anode (to lessen excitability) is the most approved method for treating irritations of the sensory nerves (neuralgias)

and of the motor nerves (local spasms, tics). It is made in the following manner: A thoroughly moistened plate of large area is applied to a point on the middle line of the body (sternum, nape of the neck, sacrum), and a similarly moistened electrode of small diameter (about 5 to 15 sq. cm.)* over the diseased nerve, *i.e.*, over the place where this nerve is nearest the surface, or at its supposed center of disease. Then with the electrodes applied we include the desired number of cells in the circuit (fewer for the neck and head than for other parts of the body, see page 171), and with the help of the rheostat, turning its handle forward slowly and gradually (creeping) from the 0 point, we turn on the galvanic current until the needle of the galvanometer shows a current-strength between $1\frac{1}{2}$ to 6 ma. The prescription fluctuates between these intensities; which of them we choose depends upon:

Trigeminal Neuralgia

(1) The position of the nerve. In the trigeminus (on the head) we should use at most about 2 ma.;† at the brachial plexus we can use much more; at the ischiadic as much as 8 to 10 ma.

* According to the thickness of the skin to be penetrated, *e.g.*, at the trigeminus we will choose an electrode of about 5 sq. cm., at the ischiadic one of 20 sq. cm. or more.

† Within the last years Bergonié, and after him L. Dubois, Guilloz, and others, have recommended currents of greater strength in trigeminal neuralgias: an anode of from 200 to 250 sq. cm. area applied like a half mask to the trigeminal region, fastened with two rubber bands and covered with felt, and a kathode of from 400 to 500 sq. cm., remain on for from fifteen to twenty minutes. The galvanic current is turned on, and is increased from 35 to 50 ma. in the first seven to ten minutes, and then gradually decreased to 0 again.

(2) The length of the case and the duration of the treatment. In new cases and in the first treatments we use weaker currents; gradually we increase the intensity.

(3) The patient's sensibility. Many persons feel a severe burning at certain points with strengths under 1 ma., so that we are forced to use weaker currents. In general it will do no harm always to choose a current strong enough to give the patient a slight sensation—at least a feeling of gentle warmth. We allow the electrodes to remain about four to eight minutes, then gradually we turn off the current, exclude the cells also, and then remove the electrodes. If several nerve points are to be treated, *e.g.*, several branches of the trigeminus, then, after the gradual turning-off and the removal of the electrodes, the second and third points are treated in like manner. We should hardly undertake more than three points at one treatment.

Local Spasms

In local spasms, *e.g.*, facial tic, we proceed in exactly the same manner as in neuralgias. In these cases we may also make gentle stroking movements over the region, with small current-strengths and without turning off the current; at the same time the electrode must not be removed from the skin (labile anode). It is noteworthy that the so-called sympathetic galvanization (see page 202), or the "rising" faradic currents (see page 186), have been recommended for such tics.

During the treatment we must always watch the galvanometer closely and keep one hand on the rheostat handle; for as the current acts the resistance of the body lessens, as has been said above, and the current-strength

increases in proportion. Therefore we must always regulate the rheostat in order to keep the current strength constant.

In order to keep our hands free we must, if possible, fasten one electrode to the body of the patient, *e.g.*, the kathode on the patient's collar, as a nape electrode, or on the sacrum, while the different electrode may be held by the patient himself; or the patient may hold a large plate (Fig. 30) on the sternum and the other electrode on the point where the pain is located. But we

FIG. 30.

must be careful that during the treatment, *e.g.*, when a strong burning occurs, the patient does not remove the electrode, and we must instruct him to tell at once when the stronger burning begins, and to hold the electrode firmly. We should never let the patient hold an interrupting electrode (see page 172).

Brachial and Ischiadic Neuralgias

2. Descending galvanic currents are likewise supposed to have the effect of lessening excitability. We can use them advantageously in irritations of such nerve-trunks as lie near the surface of the skin and are more extensively accessible to treatment, *e.g.*, in neuralgias of the brachial plexus, the intercostal nerves, the sciatic, etc. In such cases we choose two electrodes of equal diameter, about 15 to 30 sq. cm., and apply both, well moistened

and far apart, on the course of the nerve, the anode centrally, the kathode peripherally—*e.g.*, with the ischiadic nerve the anode is applied in the middle of the lower gluteal furrow, the kathode directly over the hollow of the knee where the nerve branches; with the brachial plexus, the anode in the supraclavicular hollow, the kathode on the internal bicipital sulcus, etc. The current-strengths are chosen on the same principles that were discussed above (page 177). The same is true of turning the current on and off and of the length of the treatment.

In treating ischiadic neuralgia we may galvanize by stations—*e.g.*, station 1, from the origin of the lumbar nerves to the point designated above under the gluteal furrow; station 2, from the latter point to the hollow of the knee; station 3, from the hollow of the knee to the region of the malleoli. Between these several stations the current should be slowly and gradually turned off. The patient may sit on the buttock of the side not being treated, while the other projects beyond the edge of the chair.

Old Ischiadic Neuralgias

3. In long-standing cases of neuralgia, *e.g.*, in old cases of sciatica, we can use the so-called Volta's alternatives, *i.e.*, we apply the electrodes in the manner described under 2, and then without moving them we take hold of the handle of the current-reverser and reverse the current quickly and frequently. Thus a strong stimulation is caused which is said to have a favorable effect on the slow "torpid" healing process.

4. We may apply the faradic current in neuralgias—

not in local spasms—in the form of the faradic brush (Fig. 31), brushing or stroking with this brush-shaped (or a pencil-shaped) electrode, with not too weak faradic currents, thus trying to produce a reddening of the skin. We may assume that such a procedure works as a "derivative." Faradic Current in Neuralgias

Likewise the faradic moxa, which consists in applying a brush or some other dry electrode stationary at the point of pain, and turning on an induced current of

FIG. 31.

gradually increasing strength, has good effects. However, in trigeminal neuralgias it is not to be recommended.

In neuralgic pains which owe their existence to an organic cause, *e.g.*, neuritides, the same methods may be used; they will then have an essentially symptomatic significance.* Acute attacks of neuralgias and neuritides are not suited to electrical treatment, tho in the other cases it gives generally acknowledged favorable results. Neuritides

For a further discussion of the treatment of neuralgia, see in the chapters on Franklinization, Teslaization, sinusoidal currents, and permea-electric treatment.

* For the electro-therapy of neuritic paralyses, see below.

Paralyses of the Peripheral Nerves.

Peripheral Paralyses

1. If the point of lesion is directly accessible to treatment, *e.g.*, in contusion paralysis of the radial nerve, we apply a galvanic kathode stationary at this point—that is, at the turning-point of the radial on the upper arm, and send a not too weak current through the nerve, 4 to 8 ma. The diameter of the electrode should be about 20 to 30 sq. cm. The other electrode, the indifferent one, is applied at any of the customary places, and has a correspondingly large diameter, about 100 sq. cm. or more. The length of the treatment is about ten minutes. During this time we let the patient make attempts to move, and finally help him a little. We may proceed in the same manner in other paralyses, *e.g.*, in the facial or the brachial plexus.

Radial Paralyses

2. Muscles affected with paralysis may be made to contract singly by the faradic current—local muscular faradization, with a moving electrode—if their reaction to the faradic current is not lost. For this purpose we proceed in the same way as in conducting the electrical examination, making several closings, with currents of medium strength, by means of the interrupting electrode over each muscle of the diseased region; the contractions should be clearly visible, not minimal. We can also undertake to stimulate, without the indifferent electrode, with two electrodes of equal diameter (5 to 10 sq. cm., one of them an interrupting electrode), applying them in the course of each muscle and closing the circuit there several times. That a favorable effect on the nu-

trition of paralyzed and atrophied muscles follows such stimulation is to be accepted as certain.

The method is contraindicated (1) when spasms of the muscles in question exist, in which case it may be actually injurious; (2) in faradic inexcitability, where it is useless.

Single Muscle Galvanization

3. Galvanization of single muscles with the kathode is employed in a manner analogous to 2, especially in cases of paralysis in which the faradic excitability is lost; but it is, of course, also applicable in other cases. In this application the current-strength is medium, *i.e.*, sufficient to cause plainly visible contractions. Generally this will be the case with about from 1 to 5 ma.

We may also proceed advantageously in the following manner: we apply an anode at the sternum or on a proximally located part of the nerve-trunk (*e.g.*, in radial paralysis at the turning-point on the upper arm, and so on), a kathode, as exciting electrode, at a point in the diseased region,* turn on a current which will cause plain muscle contractions, and with this current we stroke the electrode (closed and without removing it from the skin) back and forth for several minutes over the entire diseased region. This labile kathodal galvanization has the advantage that with it one can avoid all sudden current fluctuations, especially if he is careful to turn off the current gradually after the treatment is ended and before he removes the electrodes. Therefore

* In cases of reversal of the contraction law, and in "preponderance of anodc contractions," the kathode is chosen for the treatment of paralyses.

Facial Paralysis

this method is particularly suited for treating paralyses in the head and neck, and also especially facial paralyses, in all of which current fluctations—from opening and closing the interrupter, etc.,—are absolutely to be avoided. Current-strength on the face and head not more than about 3 ma. During this labile treatment also the attempts at motion mentioned under 1 are to be recommended.

Neuritic Paralyses

4. In cases of decided atrophy, especially in neuritides (lead palsy, post-diphtheritic paralysis, or multiple neuritis of all kinds), we can also apply the so-called combined current in the form of labile galvano-faradization of the single muscles. This is done in the following way: on every large apparatus there is on the current-changer (see page 28) besides the two contacts *C.* and *S.* (through which we can get either the faradic [secondary, *S.*] current, or the galvanic [contact, *C.*] from the same binding-posts) a third contact *CS.* (see page 9, Fig. 5). If we turn the handle of the changer to this contact, we can get both kinds of currents simultaneously through the two binding-posts; then we apply an exciting electrode (with an indifferent anode) to one of the muscles to be treated, include the desired number of cells, and turn the handle of the rheostat forward, upon the clock-dial device, until we see a forcible galvanic contraction follow the circuit closing. Then we put the faradic current into action (by plugging the little block) and push the secondary coil forward until we get a visible faradic (tetanic) contraction. With this strength of the combined current we stroke the closed electrode over

the entire diseased region for several minutes. This proceeding has a very strong stimulating effect upon the muscles. If we have no current-changer, but perhaps two separate portable apparatus for the galvanic and faradic currents, we need only place the two apparatus side by side, fasten a conducting-cord to each of them and connect the two free binding-posts by means of a bit of wire. Then we proceed in the same manner as described above. The Combined Current

At points where all excitability, even the galvanic, has disappeared, all electro-therapeutic methods are in vain. Likewise, if secondary contractions occur in a paralyzed region, *e.g.*, in facial paralyses, we had better replace the electric treatment with another (massage, etc.).

For a further discussion of treatment of paralyses and atrophy, see Chapter X., Franklinization.

(b) Diseases of the Muscles.

1. In paralyses of muscular origin the treatment is to be carried out exactly according to the same principles as have been mentioned in the previous division. It is a question chiefly of progressive muscular dystrophies. Since in these a complete loss of faradic excitability usually occurs only very late, we shall be able in most cases to apply local faradization or galvano-faradization with the combined current (see page 184), besides the labile kathodal galvanization of the separate muscles. Dystrophies

2. Local inflammations of the muscles (myositides)

Myositides as they often occur, for instance, in the cucullaris, sterno-cleido-mastoid (rheumatic caput obstipum) and the muscles of the back, we treat, either

(*a*) With the local galvanic anode, as the neuralgias (see page 176), or

(*b*) With the so-called increasing currents (Frommhold). A small exciting electrode, preferably uncovered and dry, *e.g.*, a metal button or brush, is applied firmly at the point where the pain or the swelling is located; then a weak faradic current is turned on and gradually strengthened by slowly pushing forward the secondary coil. If we pause after each slight increase and allow the pain of the faradization to subside, which generally it does soon, we can reach very considerable current-strengths after about ten to fifteen minutes of this gradual increasing. Then we carefully allow the current to sink again, and repeat this proceeding several times. In favorable cases a single treatment of this kind decreases pain and contraction considerably.

(*c*) We can also apply a sort of electrical massage with a roller-shaped electrode (Fig. 32) with faradic currents of medium strength (see note, page 190) applied for several minutes at the painful point (by stroking lightly). We may also make use of the faradic brushing or penciling in order to produce an "anti-spastic" effect.

Rheumatic Affections 3. The same methods, especially those mentioned under *c*, are applied in more extended, so-called rheumatic affections of the muscles. In these electric baths are also to be recommended (see below, page 197).

Furthermore, we can use a manual electric massage in these cases in the following manner: The physician fastens a neck-electrode in his coat collar, the patient holds the other electrode on the sternum, the nape of the neck, or at the sacrum; then a weak faradic current is turned on and massage is given in the usual manner with slightly greased hands. Stronger currents are to be avoided. Aside from their painfulness, they cause dis-

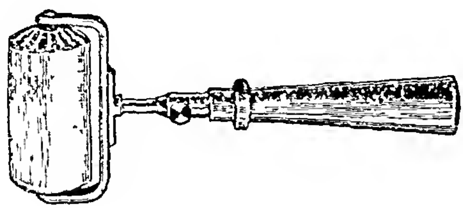


FIG. 32.

turbing contractions of the muscles in the masseur as well as in the patient (compare the chapter on Franklinization).

4. Muscle spasm (*e.g.*, in the calves) can be treated with the labile galvanic anode (see page 178). Faradic treatment is inadvisable because it causes muscular contraction. Likewise in treating myotonic conditions electrically (myotonia congenita or acquisita), we should at most use the labile anode treatment, at all events not the faradic current. Muscle faradization in "pseudoparalytic myasthenia" (to be sure, a very rare affection) is especially to be warned against, because of the accompanying easy exhaustion by electric stimulation. (For myasthenic reaction, see page 143.) Spasms

(c) Diseases of the Spinal Cord.

1. Local galvanization of the spinal cord. This may be performed with stationary electrodes (stabile galvanization) or with one stationary and one moving electrode (labile galvanization).

Stabile Galvanization

(*a*) Stabile galvanization with descending currents. Two well-moistened plate electrodes of equal area, about 20 to 50 sq. cm., are applied at the two ends of the spinal medulla, the anode at the vertebræ of the neck, the kathode at the lower end of the vertebral column. Then a current of about from 3 to 8 ma. is turned on, and is allowed to act about eight to ten minutes. It is certain that with this method current streamers strike the spinal medulla, and it is supposed that they exert a favorable effect there on circulation, nutrition, and metabolic assimilation. This method of procedure is especially recommended for treating tabes dorsalis; but it may also be applied in other column and transverse diseases. Contra-indications against this proceeding are acute diseases, *e.g.*, cases of acute myelitis, recent hematomyelias, etc.

Tabes Dorsalis

In older diseased areas, *e.g.*, in cases of poliomyelitis of long standing, it offers no advantages, but a symptomatic procedure is to be preferred. The attempt to influence disease centers in the spinal cord directly by applying two small electrodes at both sides of the diseased part is generally not worth recommending. It should be discarded outright in acute or bacterial dis-

Chronic Poliomyelitis

eases (purulent or tuberculous); and it is not to be advised in tumors (gliomas, etc.). In using this method care must be exercised that the two electrodes do not touch.

(*b*) Labile galvanization with the kathode. A large anode is applied at the sacrum or at the nape of the neck, a kathode of about 30 sq. cm. diameter, well moistened, is stroked up and down the spinal column for several minutes. In regard to current-strength, indications, and contra-indications, the same holds true as in (*a*). It is well to keep a sharp eye on the galvanometer needle during the stroking and to regulate the current-strength with one hand on the handle of the rheostat, because often the skin resistance differs very much at different parts of the back, and great fluctuations in the current-strength may occur on account of this. In stroking the dorsal region a reflex cough often occurs (especially if the galvanization on the chest and back be rather strong). Labile Galvanization

(*c*) Transverse electrization of the spinal column. An anode is applied at the sternum, a kathode of about 30 sq. cm. diameter on the spine. In focal diseases the Ka. should remain stationary; in column diseases (tabes, etc.) it is moved back and forth over the vertebral column—labile. Here also the current-strength should be carefully regulated, as in (*b*). Transverse Electrization

2. Sympathetic galvanization (see below under "Chorea") is recommended by many writers even for spinal diseases of all kinds. Its use is very questionable.

3. For symptomatic treatment of spinal diseases those

rules hold good, some of which have been mentioned, others of which will be discussed later—that is:

Spinal Paralyses

(*a*) For paralyses, *e.g.*, the poliomyelitic or the myelitic, the treatment is described on page 181 and following.

In spinal diseases, especially, local faradization of the spastic muscles had better be avoided when spasms exist and be replaced by labile anode treatment. In flaccid palsies, on the contrary, we should apply galvanization with the kathode or galvano-faradization (or even faradization).

(*b*) Pains and paresthesias, if they are limited as to locality, may be combated with the local anode (see page 176); if more extensive, *e.g.*, the lancinating pain or backache in tabes, with the faradic brush and medium current on the leg and at the back (for five to ten minutes).

Medium faradic currents are such as cause visible reddening of the skin, visible but not painful contractions of the muscles, with the stroking electrode.

For hyperesthesias faradic brushing, and that with rather strong currents, is also to be recommended.

(*c*) In regard to the treatment of bladder diseases, sexual diseases, vasomotor disturbances, etc., see pages 207, 200, 205.

(d) Diseases of the Brain.

Head Galvanization

1. Local galvanization of the head has been recommended, not only for cerebral focal diseases (hemorrhages, softenings, inflammations, tumors), but also for

the more extensive diseases of the brain and its membranes (arteriosclerosis of the arteries of the brain, meningitis, etc.), and even for progressive paralysis and psychoses of all kinds. A galvanic current is to be conducted either from the forehead to the nape of the neck or from both temples through the craninm. For this we choose large, almost equal, plates of about 50 to 100 sq. cm. area, the An. on the forehead, the Ka. at the nape of the neck (in the shape of the nape electrode, see page 89); we carefully turn on a gradual cnrrent of from ½ to 2 ma., and after about five minntes carefully turn it off. Or we apply the electrodes at the temples and galvanize in the same way, applying the positive pole first to one side, and then, after carefnlly turning off as above, change the direction of the current.

It is to be assumed as certain that in this procedure current streamers strike the brain, which fact may be inferred also from the nnavoidable phenomena which often accompany even a careful turning on and off (flickering, dizziness, etc.). But what effect the current has in the special case of the disease process in question can not be determined; it is just as likely to be injurious as beneficial, and it is therefore generally advisable in cerebral diseases, especially in focal diseases resulting from alterations in the blood-vessels, and also in alterations of the blood-vessels without any apparent focal symptoms, to employ this very delicate method either not at all or else with the very greatest care.*

* François Franck and Mendelssohn have recently defended this view very energetically on the strength of experimental and clinical

Especially must one not be led to use greater current intensities, or even to cause current fluctuations, by the fact that the patients say that they do not feel the current. This method is absolutely contra-indicated in all acute diseases (recent hemorrhages, *e.g.*), and in all purulent or febrile diseases. This same galvanization of the head often produces good results in functional diseases, and is to be highly recommended for them, as will be more fully discussed below. One may also try this procedure in slight functional psychoses.

Cerebral Hemiplegias

2. The symptomatic treatment of cerebral paralyses has a close connection with what has been said of the treatment of paralyses in previous divisions. Since the faradic excitability is almost always retained in these paralyses, we may advantageously apply local faradization (see page 182) to the paralyzed muscles, so far as these are not in a state of contraction; *e.g.*, local faradization of the extensor muscles of the upper extremity, paralyzed in hemiplegia, if they are in flexed contraction; faradization of the flexors of the lower extremity, if it is in extended contraction (lower leg flexor and dorsal flexors of the foot; favored muscles, according to Wernicke and L. Mann). In this way we will (1) temporarily remove the unpleasant feeling of contraction, (2) improve the nutritive condition of the paralyzed

studies. They consider galvanization of the head contra-indicated outright in all organic disease of the brain and in epilepsy, and only permissible in the treatment of neuroses. On the other hand, Leduc declares that he has influenced hemiplegias, aphasia, paralysis of the eye muscles, etc., favorably with very strong currents (10 to 40 ma., gradually increasing for ten to twenty minutes).

muscle by exciting contractions, or, in Goldscheider's opinion (see page 167), we shall be able to "pave the way" to recovery by means of the feeling of contraction transmitted from neuron to neuron. Wernicke conjectures that it calls forth motor impressions in the cerebral cortex which may influence the paralysis directly in a beneficial sense.

With the above-named limitations, we may try galvanization cautiously for headaches and dizziness (see under 1). Occasionally also we may employ the "faradic hand" (see page 198). The therapeusis of cerebral paresthesias, pains, etc., is practised according to the principles often explained. Galvanization of the head may also be used cautiously in arterio-sclerotic dizziness. Headaches, Vertigo

In buzzing of the ears, double-sided galvanization of the ear is employed; two electrodes of equal size, the anode stationary on the affected ear, are used, with a current strength of from 2 to 5 ma.

3. Many writers defend galvanic treatment of paralyses of the eye muscles; they advise either galvanization of the head or the so-called sympathetic galvanization (see "Chorea"). Good results are also said to have been obtained in atrophy of the optic nerve with these methods, as well as with cautious stabile and labile galvanization on the closed eye. The muscles of the eye, except the levator palpebræ superioris muscle (see page 63), are not accessible to direct electrization.

4. The diseases of the medulla oblongata may be treated tentatively with cross galvanization through both mastoid processes (two electrodes of the same size, of Oblongata Diseases

about 30 sq. cm. diameter). Special caution in turning the current off and on gradually is necessary; the current strength should not exceed 2 ma. This method has been tried especially in bulbar paralysis. The producing of galvanic swallowing (see page 67) by stroking the side of the neck with a Ka. of about 15 sq. cm. diameter, with 3 to 6 ma., is recommended for this disease.

Asphyxia

Attention should here be called to the fact that the faradization of both phrenic nerves has been employed beneficially in asphyxia.

(e) Functional Nerve Diseases and those of Unknown Origin.

HYSTERIA, NEURASTHENIA, AND HYPOCHONDRIA.

Hysteria, Neurasthenia, Hypochondria

In treating these diseases the factor of suggestion naturally plays the chief part, so that really every method may be used which can produce a psychic effect in the special case. In general it would seem advisable first to try the faradic current in perceptible current-strengths, because this, through the greater sensible impression, directs the attention of the patient in a greater degree to the part treated. By this we do not mean that, in certain conditions, the galvanic current applied, *e.g.*, at the head, does not produce a greater psychic effect. Psychological study of the individual case, cleverness on the part of the physician, tact in the choice of a method and ingenuity in varying the treatment, are nowhere so absolutely necessary as in the therapeusis of these functional conditions.

Besides pure suggestion, the importance of which for the electrical treatment of the diseases in question can not be overestimated, the following methods may be effective in their electro-therapy:

1. The production of muscle contractions, for instance, in the cases in which the diseases named affect individuals with weak muscles, and especially in connection with the so-called "feeding-cure" in which general faradization as an aid to general massage might, in a measure, take the place of the lacking active exercise in bedridden patients.

2. The stimulation of circulation, not only in the skin but also in the deeper tissues, whereby a favorable effect may be produced on the metabolic assimilation and on the subjective state of general health (increase of perspiration, of the appetite, nutrition, etc.). **Effect on Circulation**

3. As a result of strong faradic skin stimulation, a manifold reflex action on the central nervous organs, even on their most central parts, the disturbance of whose function evidently plays the chief part in these diseases.

In the therapy of these diseases we distinguish: (*a*) methods of general electric treatment; (*b*) methods of local symptomatic treatment. Of methods of the first kind there are to be mentioned:

(*a*) In functional nervous diseases, especially in patients who are using a so-called "feeding-cure," a general faradization of the body is to be recommended because of its refreshing and stimulating effect on the activity of the general nervous and circulatory systems. **General Faradization**

It is applied in this manner: using medium (not too strong) faradic currents with a brush or a moistened massage roller, we stroke and tap the arms, chest, abdomen, back, and limbs of the patient one after another for several minutes. The whole proceeding need not last longer than fifteen to twenty minutes. Altho the first treatments leave a certain feeling of exhaustion, the beneficial effect often appears after a very few days.

General Galvanization

(*b*) General galvanization may also be tried. Apply the Ka. as a large plate electrode at an indifferent point, while the An. of smaller diameter, with the usual precautions, is stroked over the various parts named above for about a quarter of an hour. This is especially suitable for the rather frequent cases in which faradic currents can not be borne at all. We begin with very weak, just perceptible currents, and increase the current-strength gradually.

Central Galvanization

(*c*) "Central galvanization" is the name of a process in which a large Ka. is applied at the pit of the stomach, while the An. is moved, being applied two minutes on the forehead, two minutes at the nape of the neck, and about five minutes at the "sympathetic" (see "Chorea"). Of course the current is turned off and on gradually at each station and reapplied at the next; then follows a labile galvanization of the back.

The parts which are the seat of special disorders are then to be treated according to the often named principles.

An action of the current on the whole body may also be obtained in the cases here in question by

(*d*) Electric baths. The faradic or galvanic current may be conducted to lukewarm water in wooden, porcelain, clay, or stone tubs. Two principal forms of baths are recognized: the monopolar and the dipolar. In the monopolar galvanic bath one pole (*e.g.*, the Ka.) in the form of a large plate electrode is connected with the water, while a covered and moistened rod, which the patient grasps with his hands, or a large back-plate (400 sq. cm. diameter), against which he leans, is connected with the other pole (*i.e.*, the anode) and serves in a way as the indifferent electrode. We call it a kathode-bath if the water contains the kathode, and *vice versa.** In a dipolar galvanic bath both electrodes are connected with the water, and the patient touches neither. These baths, especially with descending currents, have a soothing effect, which may be heightened by applying a rubber partition to the body in the bath, which strikes it in the middle, and, as it were, bisects the tub (two-cell bath). Then the whole current, which otherwise forms current streamers in the water, must pass through the body from one electrode to the other. The current-strength attains 50 to 100 ma. and more. The current is turned on cautiously, after the patient is in the bath. At first weak currents are chosen, later on stronger ones. The duration is at first about ten minutes, and increases later. Pain or similar effects do not occur, even with large current-strengths. In regard to technics, the same holds Electric Baths.

* These names should really be exchanged, since the electrode which is applied immediately to the body obviously has greater effect on it than the other.

true of faradic baths. Of these (as also with the galvanic) decided preference should be given to the dipolar baths. The effect is similar to that of general faradization—mainly refreshing.

To avoid wandering current streamers in the water as much as possible, Schnée has constructed a "four-cell bath." It consists of four little porcelain tubs, of which two form the arms of an armchair, and two (deeper) stand at the foot of the chair. The four are connected with the source of the current and can be included in the circuit in any desired order. This treatment is recommended in various disorders—diabetes, arthritis urica, etc.

Franklinization might be regarded as the fifth form of general electric treatment of neuroses (see Chapter X., "Franklinization").

Symptomatic Therapy

Of the details of symptomatic therapy, which in the main has a connection with the principles already mentioned so often, the following may be mentioned especially for these diseases:

1. Functional headaches and dizziness in those suffering from hysteria and neurasthenia may be treated:

Headache and Vertigo in Neurasthenia

(*a*) With galvanization of the head in the way fully described on page 190.

(*b*) With sympathetic galvanization (see "Chorea").

(*c*) With the "faradic hand." The physician applies one of two electrodes of equal size to his own body, holding it in the hand, and the other electrode is applied in the usual way to the body of the patient (*e.g.*, at the sternum or the nape of the neck); then with his free

hand, using a weak faradic current, the physician gently strokes the head of the patient for several minutes. It is well not to expect too much from the suggestive effect of this method. Compare also Franklinization (head douche).

Functional Backache

2. Hysteric, neurasthenic, or hypochondriac backaches are treated as the other functional paresthesias and hyperesthesias, with the brush or the massage roller. Galvanization of the back, of course, may be tried also. For the symptomatic treatment of special local pains (*e.g.*, ovaralgia, mastodynia) the general principles hold good: anodal treatment, gentle brushing, faradization, etc. For other methods see Chapter X., Franklinization.

Hysterical Attacks and the Like

3. What has been said above of the effect of every strongly suggestive method of treatment holds good, especially for hysterical attacks (aphonias, paralyses, etc.) and contractures. Thus, *e.g.*, one can apply local muscle faradization or, better still, galvano-faradization in paralyses, internal laryngeal faradization in aphonias (see below under "treatment of internal diseases").

In cases of not too long standing, and especially in youthful sufferers from hysteria, good results are sometimes obtained with the so-called "surprise treatment." We suggest to the patient that the symptom in question will be removed by one electrization. We turn on a strong faradic current and apply a brush electrode (or some similar one) causing sudden sharp pain at the point at which the symptom occurs (for instancc, to the laryngeal region in aphonia, to the brachial plexus in paralysis of the arm); we allow it to remain there stationary a short time, and then command the patient to utter a sound or to move the arm. We repeat this process several

times at short intervals, suggesting as before and at the same time quietly and firmly persuading the patient. Thus occasionally we may see a long-standing symptom disappear after a single treatment. To make sure of the result, we may repeat the treatment several times during the following days, then finally with weaker currents. But this method is very violent, and, moreover, not at all reliable; it fails rather often, and thus, naturally, the suggestibility of the patient suffers great damage, not only for this, but for other therapeutic methods. We must remember before having recourse to this procedure that it is a sort of a game of chance. In spite of that, it is sometimes advisable in recent cases, because by means of it one is often able to deprive professional hypnotism of its best victims.

Traumatic Neuroses

4. For local disorders in neurasthenia we proceed according to general principles. It might be mentioned particularly that a special method is not given for patients with neurasthenias, hysterias, and hypochondrias of traumatic origin, in cases under the accident-insurance law. Care should be taken not to use too strong faradic currents to "frighten pretenders," as is done in many "sanatoria."

Sexual Disorders

5. For the very frequent sexual disorders (impotence, pollutions, etc.) we may either try a brushing of the lower vertebral column with the faradic current, or apply a labile treatment in the same region with the galvanic current (as described on page 189). If we wish to use the electrotonic principle in these complicated cases, we may employ the An. as the moving electrode in increased sexual excitability, the Ka. in decreased excitability. A treatment from the lumbar (An.) region to the perineum (Ka.) with descending currents (see page

188) is certainly often beneficial. But it is hardly to be believed that all these proceedings have any other than a suggestive effect. Therefore special prescriptions as to current closing are not necessary; in general, use perceptible but not too strong currents. A direct treatment of the genitals (internal electrization or external faradization) is to be earnestly dissuaded. *General treatment is the best for all such cases.*

6. For insomnia, galvanization of the head (especially in the evening) is often employed with favorable results. Nape or sympathetic galvanization may also be used here. Electric baths are to be tried especially. (Compare also the chapters on Franklinization, Teslaization, and Permea-electric treatment.) **Insomnia**

7. Conditions of fear in hysterical and hypochondriacal patients may be treated tentatively with sympathetic galvanization.

8. For palpitation of the heart, a local galvanic An. treatment of the cardiac region, with weak currents, is sometimes to be recommended (in this an indifferent electrode should be applied at the nape of the neck or at the sternum). Or descending currents may be used: the An. at the neck, under the lobe of the ear; the Ka. at the heart. We may use the sympathetic galvanization (see below) for this disturbance also, as well as for vasomotor and secretory disorders of a functional nature, *e.g.*, for hyperhidrosis, blushing, etc. **Palpitation of the Heart**

9. In regard to trembling see page 203. The treatment of functional stomach and intestinal disorders, etc., will be discussed in "The Treatment of Internal Dis-

eases," page 209. For diseases of the bladder see "Nocturnal Enuresis," page 207. For buzzing in the ear see page 193.

Chorea and Athetosis.

Chorea and Athetosis

The electrical treatment of chorea and athetosis presents, in general, no brilliant prospects. Avoid the faradic current and apply either a local galvanization to the spasmodic parts with a moistened, moving anode of small diameter (about 20 sq. cm.) with weak currents, about 3 ma., with a larger Ka. applied at the jugular hollow; or try:

Sympathetic Galvanization

(*a*) Sympathetic galvanization of the neck. One electrode (An.) of small diameter (about 5 sq. cm.) is applied on the neck in the region under the ear-lobe, behind the descending ramus of the lower jaw; a second (Ka.) of like area in the jugular hollow. A current of about $\frac{1}{3}$ ma. is turned on (cautiously, gradually) and allowed to act for several minutes. Then it is cautiously turned off again. The Ka. may be applied also at the symmetrical point of the other side, or in the region of the lateral processes of the lower vertebræ of the neck, on the other side.

(*b*) Galvanization at the nape of the neck. The An. (15 to 30 sq. cm. diameter) is applied at the nape of the neck, the Ka. (indifferent, about 100 sq. cm. diameter) at the sternum or in the jugular hollow. The current strength should be from 2 to 5 ma.

Paralysis Agitans.

Paralysis Agitans

Galvanization of the head has been recommended for recent cases. As for the rest, what has been said of tremor holds true here. Great results are not to be expected here either. In cases of long standing nothing can be done electro-therapeutically; at most, electric baths might produce an improvement.

Tetany.

Tetany

The treatment is similar to that given for local spasms (see page 178)—that is, principally galvanic anode treatment with weak currents.

Tremor.

Tremor.

If tremor is a symptom of another disease (multiple sclerosis, intoxications, Basedow's disease, hysteria, etc.) it is generally not taken into consideration electro-therapeutically. Occasionally, however, it occurs rather idiopathically (essential, congenital hereditary, senile tremor, etc.), or it dominates the disease picture (*e.g.*, in many cases of hysteria).

Then we may try to produce an improvement by faradic brushing with not too strong currents, by sympathetic or nape galvanizations. But we must not entertain great expectations in this direction. Here, too, in the cases which are benefited, the result is probably purely suggestive. Electric baths are also recommended (see page 197).

OCCUPATION NEUROSES (WRITER'S CRAMP, ETC.).

Occupation Neuroses

We can usually distinguish different forms of these, namely:

1. A sensory;

2. A motor, and in this again,

(*a*) A paretic,

(*b*) A spastic, and, if we wish,

(*c*) A tremor-like form.

1. In the sensory forms, which manifest themselves mainly in paresthesias or pains (as, *e.g.*, often in violin-players' and telegraph-operators' neuroses, etc.), and in which motor disorders are lacking, a faradic brushing of the parts in question (*e.g.*, fingers, hand, etc.) is advisable; or a stationary or labile anodal treatment or increasing faradic currents (see page 186) may be employed.

2. (*a*) The paretic forms, as they occasionally occur in writers, pianists, seamstresses, etc., are treated according to the principles which obtain for all the other forms of paresis—that is, with local faradization of the muscles or (Ka.) galvanization, or with galvano-faradization of the affected muscles—that is, the muscles especially used in the occupation in question (*e.g.*, in writer's cramp, the muscles of the ball of the thumb, the interossei muscles, hand and finger flexors, etc.).

(*b*) In the most common, the spastic forms, on the contrary, the cramped muscles should be spared as much as possible and not be made to contract. At most they may be stroked cautiously with the labile An. with weak

galvanic currents. The same holds good for the very rare tic-like cases, such as I have seen in the upper facial region of a watchmaker. On the other hand, the antagonists of these muscles may be treated with strong local faradization (with the interrupting electrode) in order to produce a beneficial effect by their final strengthening as well as by passive stretching of the cramped muscles.

(*c*) For the tremor-like forms, the same holds true as has been said of "Tremors."

The mixed forms, which are not infrequent, should be treated according to the principles mentioned, combining in individual cases.

Vasomotor and Secretory Neuroses.

To these belong local blushing or paling, local asphyxia, erythromelalgia, transient local edema, urticaria, hyperhidrosis, etc. The prospects of electrical treatment of these conditions also are not brilliant. Galvanization of the sympathetic should be tried (see above under "Chorea"). Vasomotor and Secretory Neuroses

In erythromelalgia and in the severe forms of local asphyxia (Raynaud's disease) galvanization of the spinal cord may be tried also. In the slighter forms of local asphyxia as well as in acroparesthesias a transient beneficial result is often noted from faradic brushing of the affected ends of the extremities, *e.g.*, the finger-tips, also from local electric warm-water baths (see page 209).

See also the Appendix (Permea-electric treatment).

Hemicrania.

Hemicrania

The treatment is similar to those given on pages 191 and 198 for cephalalgia. It would probably be worth while to try galvanization of the head or of the sympathetic, especially for the so-called angioparalytic forms, *i.e.*, those accompanied by extreme paleness of the face.

Basedow's Disease.

Basedow's Disease

Sympathetic galvanization has been recommended for this disease, too. But we may also—if we regard Basedow's disease as an affection of the oblongata—use galvanization of the medulla oblongata by applying two electrodes of equal size, of moderate diameter and well moistened, to the two mastoid processes. The current is allowed to circulate first in one direction, then in the other, but special care must be exercised here in turning the current off and on gradually, and the current direction must not be changed with the circuit closed. Current-strengths should be small, *i.e.*, ½ to 1½ ma.

The galvanic electrization of the struma (or in cases in which there is no struma) of the thyroid promises the most success in the therapeusis of Basedow's disease—and in many cases seemingly with quite brilliant success. The arrangement and size of the electrodes as well as the other rules are the same as in the galvanization of the oblongata. The electrodes are applied at both sides of the struma. The treatment lasts about five to ten minutes. Here, again, the current is sent through, first in one direction, then, after being turned off cautiously and

gradually, in the other. Libotte recommends very strong currents (60 ma.), acting for a long time in this instance. Faradization of the struma with very strong currents (plate electrodes) may be tried also.

NOCTURNAL ENURESIS.

In treating this symptom, as a rule, it is better not to use bougie-shaped electrodes, of which various forms have been made and which are to be introduced into the urethra, while the other pole, supplied with a large indifferent plate electrode, is applied at the sternum or some other such point. We should never use a bougie or a catheter unless compelled by necessity. Since the bougie electrodes are not covered at the ends, they easily ulcerate the mucous membrane. Doubtless an external treatment suffices for very favorable results. For this, one electrode (Ka.) may be applied to the lumbar region and the other (An.) on the perineum, then medium galvanic (2 to 6 ma.) or medium faradic currents are turned on, or the Ka. may be applied in the lumbar region, the An. over the symphysis pubis, and we proceed in the same way; or finally, the An. is applied at the symphysis, the Ka. at the perineum. Again proceed in the same way.

Nocturnal Enuresis

In all cases medium electrodes of equal size (about 20 to 50 sq. cm.) should be chosen.

The bladder disorders of those suffering from tabes or other diseases of the spinal cord, and of neurasthenic and hysteric patients, may be treated in the same way.

Treatment with the bougie-shaped electrodes should be decided upon only in exceptional, very obstinate cases or (*e.g.*, in neurasthenic and hysterical urinary disorders) to get a certain suggestive effect. Then the faradic current is always to be preferred, or, if the galvanic must be used, the current must be continually reversed (Volta's alternative). It need not be emphasized that the most careful asepsis must be observed in introducing the electrode.

(f) Diseases of the Joints

Joint Diseases

Acute diseases of the joints, especially the purulent and other infectious diseases, are debarred from electrical treatment. For the rest, especially the subchronic and the chronic, the therapeusis is on the whole the same, however widely their etiological and anatomical basis may differ. The following methods are used most:

1. Electrization of the diseased joint with not too weak currents (faradic, or, better, galvanic), the joint being put between the two electrodes. The size of the electrodes depends upon the size of the joint; the duration of electrization is about ten minutes. An electrolytic effect of the current is counted upon here. Recently writers recommend very strong currents (up to 50 ma.) in order to produce electrolysis.

2. Rolling the region of the joint by means of the massage roller may be employed; in this faradic currents (and galvanic also) of moderate strength may be used. In regard to manual massage, see page 187.

3. It is often well to use electric baths in treating

articular diseases, and either the full baths (in extensive polyarthritis, see page 197) or local baths in more limited diseases—*e.g.*, in a subchronic or chronic rheumatic or gouty arthritis, which affects only a hand or foot, or in ankylosis of the hand and finger-joints, etc. The current may easily be conducted through the bath if an indifferent electrode is applied to the body (*e.g.*, at the sternum), and the other is sunk in a wooden or earthen vessel filled with warm water; or if the conducting wire of the other pole is connected with a current-conducting vessel (*e.g.*, a metal tub or pan) by a binding-post soldered on to it, so that the bath-pan is connected with the circuit as an electrode, as it were. Besides, the static and the high-frequency currents also are used in rheumatism of the joints (see the chapter on this subject). See also the four-cell bath, page 198.

4. In cases of muscular atrophies which often accompany diseases of the joints, local treatment of the muscles should be applied in the usual way (see pages 182 and 184).

Proceed according to the same principles in diseases of the tendons and tendon sheaths; no details need be given in regard to these.

(g) Diseases of the Internal Organs and General Diseases

Danger in Use of Electrodes Internally

Special metal electrodes are made which can be introduced into the interior of the organs, as different poles, while the indifferent electrode is applied outside. Such electrodes exist for the stomach, the rectum, the bladder,

the female genitals, the larynx, and the nose. All metal electrodes if introduced with the galvanic current may easily ulcerate the mucous membranes, therefore they are usually to be discarded. If they are applied nevertheless, then constant reversal of the current (Volta's alternatives) should be made in order to avoid ulcerations. Such electrodes (*e.g.*, for the stomach, one which can be swallowed, or one in the form of a stomach-tube, introduced after the patient has taken from one to two glasses of water) can be used better with the faradic current. Generally, they are superfluous even for this, and may be replaced by external applications of the current with the same success. Internal application should be employed only in case of necessity or for the purpose of a particular suggestive effect. External applications may be made in the following manner:

Diseases of the Stomach and Intestines

1. Diseases of the stomach and intestines are treated mainly with faradic currents, and generally with rather strong ones. Atonic conditions particularly lie within the province of electrotherapy (atony of the stomach; ectasis, either nervous, catarrhal, or that remaining after ulcer; gastroptosis, eructation and nervous vomiting; intestinal atony; chronic habitual constipation; chronic catarrh). In these cases a plate of from 400 to 500 sq. cm. diameter, thoroughly moistened, is applied to the back of the neck, while a smaller one of about 50 to 100 sq. cm. diameter, or a massage roller is applied in a labile manner in the direction of peristalsis, with pressure, across the stomach or the colon, or is applied stationary—at various places over certain points. Inter-

ruptions may also be made at these points, if the exciting-electrode has an interrupter. For this the current must be rather strong, with a duration of ten to fifteen minutes.

Many authorities prefer the galvanic current. In subacidity of the gastric juice it seems to be even superior to the faradic. In this a large indifferent back-plate (see Fig. 30) is moved over the stomach or the intestine in the direction of the peristalsis for about ten to twenty minutes with a current strength up to 50 ma. The combined current is also applied in the same way.

With this, galvanization of the splanchnics (Ka. with strong currents at the sixth to twelfth dorsal vertebra) can be combined, especially in constipation.

In most cases internal faradization (see above) is eventually also permissible. In this case the internal electrode remains stationary, while the outer one is labile. This is contraindicated in vomiting, eructation, and regurgitation. Any electrization is forbidden in recent ulcers, acute catarrhs, tumors, tuberculosis, and threatening peritonitis; it is generally discountenanced also in hypersecretion.

Strong labile faradization of the intestine—galvanization or galvano-faradization (with the Ka. at the back, or, less to be recommended, in the rectum) is said to have relieved several cases of intestinal occlusion and obstinate, acute constipation. It must be applied two to three times daily for fifteen minutes. What has been said above in regard to the precautions to be observed in internal treatment holds good here. Constipation

It has been reported that even strangulated hernias have been reduced by strong faradization of the local or abdominal muscles applied for ten to fifteen minutes.

Visceral Spasms

What has been discussed above under neuralgias and tics holds good in general for the motor and sensory irritations in the region of the digestive tract. Gastric spasms, cardiac cramp, lead colics, cardialgias, and intestinal neuralgias are generally treated with the local anode (50 to 100 sq. cm. diameter), with the large indifferent kathode applied preferably at the back. The gradual turning on and off is done as usual, only the currents are considerably stronger, up to 15 to 25 ma.

Others recommend faradic brushing or increasing induction-currents (see page 186). In so-called heartburn and nausea, galvanization of the sympathetic or vagus should be tried (descending from the upper end of the carotid hollow to the jugular, with weak currents).

Gastro-Intestinal Neuroses

The real gastro-intestinal neuroses (nervous dyspepsia, bulimia, anorexia, nervous diarrhea, membranous enteritis, etc.) are to be treated like the neuralgias. But a general treatment is here particularly recommended (general faradization or galvanization, electric baths). In dyspepsia faradization may be applied straight through the hypochondriac region.

Cramp and paralysis of the sphincter ani are treated like all other conditions of cramp and paralysis.

2. Heart diseases. Only the neuroses are treated electrically. For method, see page 201.

3. In muscular paralysis of the larynx or functional disturbances (aphonia) external faradization or galvan-

ization of the laryngeal region may be applied with a stabile or labile kathode; or weak internal galvanization or faradization may be applied without injury with a covered laryngeal electrode under the control of the laryngoscope, the indifferent one being applied at the sternum (Fig. 33). Paralysis of the soft palàte (*e.g.*, diphtheritic) is treated in the same manner.

Laryngeal Diseases

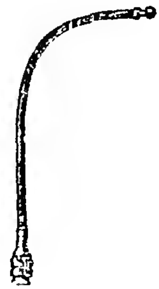


FIG. 33.

4. For bladder and sexual diseases, see pages 207 and 200. The faradic current is also said to be an emmenagogue. Faradization of the uterus is also often employed as an ecbolic.

Diseases of the Bladder and Uterus

5. In scleroderma and some skin diseases, *e.g.*, prurigo, sympathetic galvanization should be tried according to some writers. In regard to Teslaization in skin diseases, see the chapter on that subject.

Diseases of the Skin

6. In chlorosis and anemia general faradization or electric baths are often of advantage.

Chlorosis

7. For the treatment of metabolic diseases, see chapter XI. on Teslaization.

Metabolic Diseases

CHAPTER IX

II. Galvano- and Farado-Therapeutic Apparatus

It is the task of an electro-therapeutic guide to describe all or even many of the numerous apparatus or accessory apparatus which have been constructed and recommended for electro-diagnosis and treatment. It must be left to the one who wishes to acquire an apparatus to decide questions from the catalogs issued by the large firms. Here attention will be called briefly to the points which must be considered in the acquisition, choice, and use of an apparatus for galvanization and faradization. The requirements demanded of a good apparatus are: (1) Greatest possible constancy of cells; (2) greatest possible exactness and handiness of accessory apparatus; and (3) cheapness.

Constant Cells.

Constant Cells

If we put a cell together in a simple way (see page 3), immersing two metals, *e.g.*, a piece of zinc and a piece of carbon, in a fluid (acid solution), an electrolysis of the water contained in the solution, a separation into H and O, goes on during the time the metals are immersed. While the hydrogen collects on the negative metal, the carbon, the oxygen combines with the posi-

tive metal, the zinc, to form zinc oxide; if the acid contains sulphur, the oxide of zinc combines with this and forms sulphate of zinc, which dissolves in the fluid. Thus there occurs, first, a gradual decrease of the zinc; secondly, a gradual coating of the carbon; and thirdly, a gradual change in the fluid of the cell. These three circumstances contribute in producing a gradual weakening of the electromotive force of the cell. We call this process *polarization*. It finally causes the appearance of stronger and stronger contrary currents in the fluid of the cell, and thus gradually produces entire inactivity of the cell. If we use cells of this kind for working galvanic batteries, we must be careful (*a*) that the metals are immersed only while the battery is being used, and afterward are lifted out at once; (*b*) to renew the fluid after it has been used several days—that is, as soon as we have noticed that the current which the apparatus gives has gradually become weaker; and (*c*) to renew the zinc plate after it has been used for several weeks or months. Cells of a simple structure like this have been made; they form the so-called dip-batteries which are used for working the portable galvanic apparatus (for its description see below, page 222 and following).

Polarization

Dip Batteries

In order to avoid the disadvantage connected with the continual filling and repairing, and in order to get a greater constancy of action, the attempt has been made to construct so-called constant cells, in which polarization is avoided as much as possible, and consequently no wearing out, or only a very slow one occurs.

Of these cells is to be mentioned first of all:

Leclanché Cell

1. The Leclanché cell (Fig. 34), probably the most constant and most widely used cell. It consists of a zinc rod, a large carbon-manganese cylinder which surrounds the rod, and a smaller porous clay cylinder which separates the two metals from each other and extends to the bottom of the vessel. The liquid is a saturated solution of sal ammoniac. On account of the separation of the metals from each other electrolysis and the formation of contrary currents are made so difficult that polarization occurs only after an extensive use of several months. With a battery which consists of cells like these there is nothing to be done except to add some fresh solution from time to time, when a decrease in the current-strength is noticed. Only after months, or with moderate use after years, need the zinc rods be freed from the crystals which collect on them or be renewed. Thus the cell is very constant. Of the numerous forms and modifications of this cell, the one given in Fig. 34 is probably the most used.

FIG. 34.—Leclanché Cell.

Daniell-Siemens Cell

2. The Daniell-Siemens cell (drawn in cross-section in Fig. 35) was formerly widely used, but now has been almost wholly supplanted by the one described above. It consists of zinc, copper, and a diluted sulphuric-acid solution. The copper is in the form of a rod with a spiral lower end. This rod is immersed in the fluid, which also

contains pieces of copper sulphate. The zinc is in the form of a cylinder and surrounds the copper rod. Between the two metals there is a funnel, whose broad opening rests on the bottom of the jar, and whose upper part consists of glass and lower of clay. The funnel is held in position by pasteboard stuffed in around it. The clay cylinder rests on the pasteboard; the copper rod is placed in the funnel. This cell also is very constant.

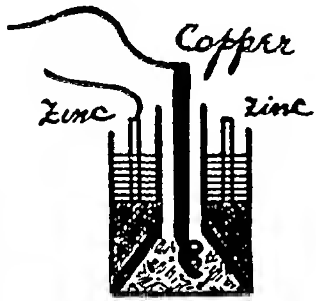


FIG. 35.—Section of a Daniell-Siemens Cell.

Dry Cells

3. There are dry batteries of most varied construction. They are used for portable apparatus more frequently than for stationary ones. They have the advantage of being easy to carry, but have the disadvantage of being rather more expensive. (For details see below.)

Arrangement of a Stationary Apparatus and of Accessory Apparatus.

Stationary Apparatus

The great majority of batteries which are used in the larger stationary apparatus consists of Lechanché or Daniell cells, such as have been described. The battery consists of about from thirty to sixty cells, which are generally arranged in a table drawer in series, as described above (page 7). Besides these, there are in the drawer two cells of the same kind (connected similarly) which are used for the faradic apparatus. The

other arrangements of a stationary apparatus for the galvanic and faradic currents have been described in detail above (page 7 and following). Of course there are numerous modifications in the construction of apparatus and accessory apparatus, which need not be discussed more fully here. Only the following points are to be mentioned:

Rheostat

As to a rheostat, there should be used preferably one of the metal rheostats of German-silver or similar wire. In the apparatus supplied by Leclanché cells the rheostat is usually for technical reasons placed in the direct circuit (see page 16 and following). For smaller portable apparatus other rheostats are used, which will be described below. The larger the rheostat is (the more contacts it contains) the finer is the gradation possible in the current-strength.

Galvanometers

The vertical galvanometer made by Hirschmann is one of the latest, and is highly to be recommended. It answers the demands made upon a galvanometer in an almost ideal manner. There are galvanometers in common use which contain a horizontal needle that swings on a horizontal scale (horizontal galvanometers). However, the vertical ones are to be preferred, because it is possible to read them easily and quickly. The galvanometers after Deprez-d'Arsonval, which can be employed in any position, are just as easily used.

The older forms of (vertical) galvanometers in which a long time is required for the needle to come to a rest in current fluctuations are not practical; before the current-strength present can be read from them, a change in it has often taken place by the lowering of

skin resistance, so that one reads a false result. The needle of the first mentioned galvanometer, on the other hand, moves evenly, and by the absence of fluctuations makes quick reading possible.

Galvanometers also are made in various sizes. The largest permit of a reading of the smallest fraction of a milliampère. Therefore they work most exactly. Many firms have recently made meters which by means

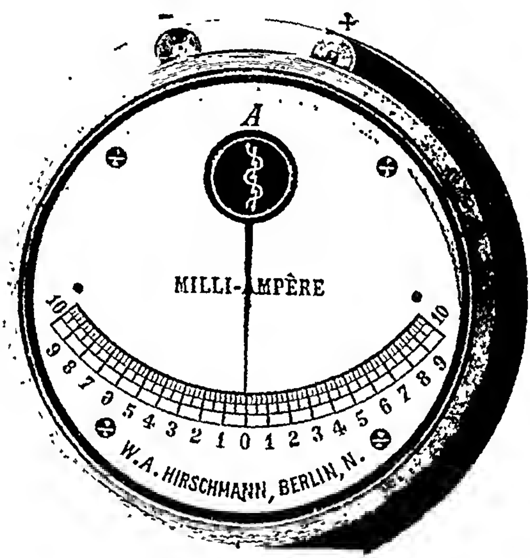


FIG. 36.

of a slight switching may be used either as galvanometers (ampèremeters) or as voltmeters, from which not only the current intensity, but also the (volt) tension can be read. This takes into especial consideration the experiments of Dubois mentioned above (page 12, footnote) according to which the Ka. Cl. C. depends not on the intensity alone, but upon the tension. So long as these

experimental results are still contested, such apparatus *is quite superfluous for the practitioner.*

Cell Collectors

Of cell-collectors, those constructed by Reinizer, Gebbert, and Schall are particularly to be mentioned. They contain a so-called double-collector (see Fig. 37) which makes it possible to include in the circuit any desired number of cells of a battery (beginning at any cell in the

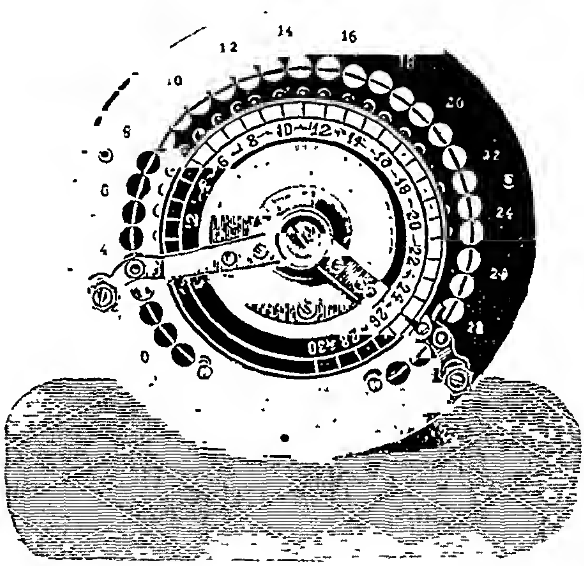


FIG. 37.—Double Collector.

series). Thus quite an even and economical use of the battery is made possible. The price of a stationary apparatus for the faradic and galvanic current which will meet all demands varies.

Connecting Apparatus

In localities where there is an electric-lighting or other direct current dynamo-plant* it is best to have the

*Alternating current plants can not be used. A transformer which changes the alternating current to a direct current is costly.

electro-therapeutic apparatus connected with a street wire. This saves the buying of cells and cost of repairs. By resistances (incandescent bulbs) included in the ap-

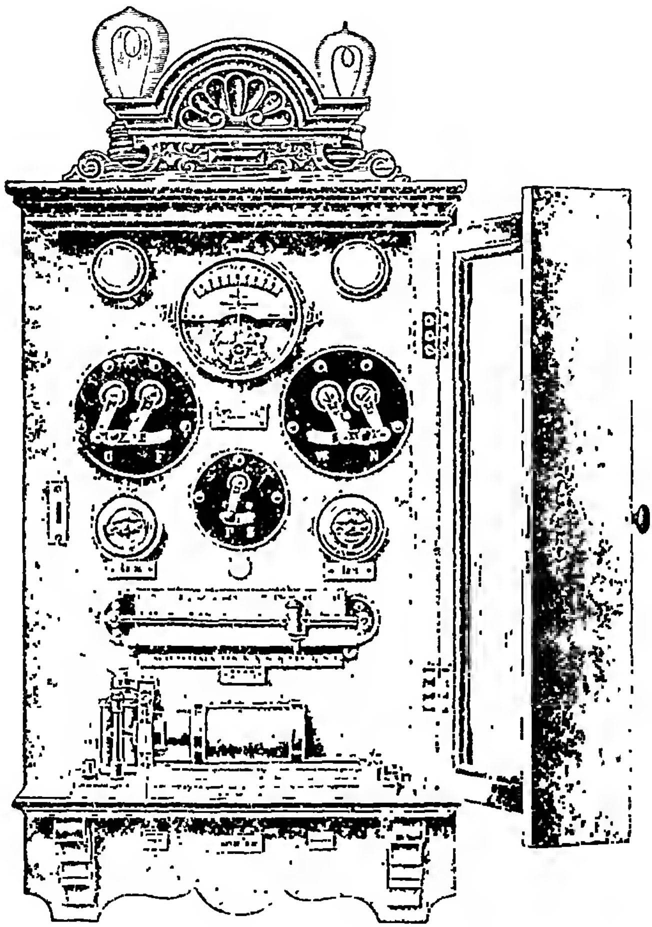


FIG. 38.—Wall Case Plate for Street Current.

paratus constructed for this purpose the current produced by the street system, which is far too strong for our use, is so far weakened as, with the aid of large

rheostats, to be practicable for diagnostic and therapeutic ends.

These apparatus are considerably cheaper than those in which cells are used. They are made either in the form of tables (cabinets), like those with cell-batteries, or in the shape of wall cases, often of very pleasing appearance (Fig. 38). The cases have the advantage of economy of space and greater cheapness, but the tables are more useful for fine current gradation because they can hold larger rheostats.

Portable Apparatus.

For treatment outside of the physician's office portable apparatus are made.

Portable Apparatus

The faradic portable apparatus are constructed (see Fig. 39) on the same principles as the stationary, only the spirals are, as a rule, smaller. The spirals and one or two active (Leclanché) cells are placed in a wooden case, which can be closed. By inserting a plug or by moving a contact-lever from the contact *R* (rest) to the contact *T* (activity), or from the contact *A* (exclusion) to the contact *E* (inclusion) the apparatus is set into action. By pulling out or pushing in the secondary spirals, or the steel core (see page 26, footnote) the current is strengthened or weakened. In many of these portable induction-apparatus it is possible to get a primary current from a binding-post designated *P* (extra current, see page 27), or from *P.S*, both currents together. The primary current has little practical significance. The smaller these apparatus are the less exact

often do they work, and the less useful are they for electrical examinations, since they usually produce only strong currents, and not the weak ones necessary for

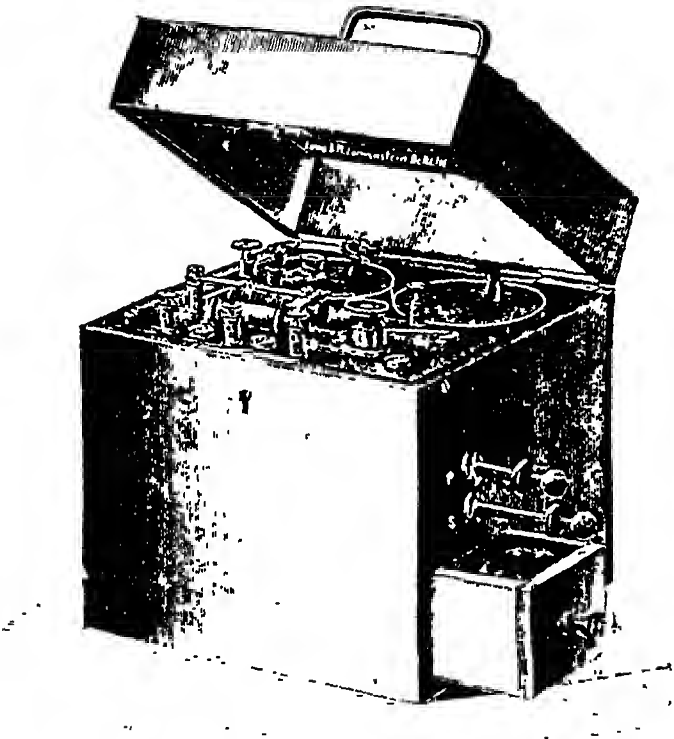


FIG. 39.—Portable Induction Apparatus with Dry Cells.

diagnosis. Portable apparatus also are often made with accessory apparatus.

Chromic Acid Cells

There are also portable induction-apparatus, which are run, not by Leclanché, but by dip-cells (see page 215). The latter are used in the form of flasks filled with a chromic-acid solution, into which a zinc and a carbon rod are plunged. These chromic-acid cells are quite service-

able also for running faradic as well as stationary apparatus; only the zinc rod must be taken out every time after use. Dry cells also may be employed for portable apparatus. They have the advantage of being safely portable and of great durability. The prices of serviceable portable apparatus vary; the cheaper ones are usually not adequate for diagnosis and finer therapeusis.

In the portable galvanic apparatus chromic-acid batteries are generally used (*e.g.*, Fig. 40). In a wooden box there is a trough which is divided into numerous compartments or cells (20, 40, 50). Each of these cells forms a separate little vessel, which is filled with a chromic-acid solution. From the plate of the box an equal number of zinc and carbon rods, arranged in pairs (20, 50), fastened by screws, hang down into the inside of the case. They are arranged in parallel rows of ten each. For each pair of zinc and carbon rods there is a corresponding metal contact on the plate of the box. By means of a lever arrangement at the side of the box the trough with its compartment filled with fluid can be raised so that the rods are plunged into the solution; then the galvanic current is generated, which is conducted in the usual way from the two binding-posts by means of insulated wires.

In this apparatus there are also found:

1. A small current-reverser (see page 21).
2. A small absolute galvanometer* which is made by

* The older apparatus contained in place of this a so-called galvanoscope, which only indicates whether a current is present or not, but does not make possible a reading in absolute measures.

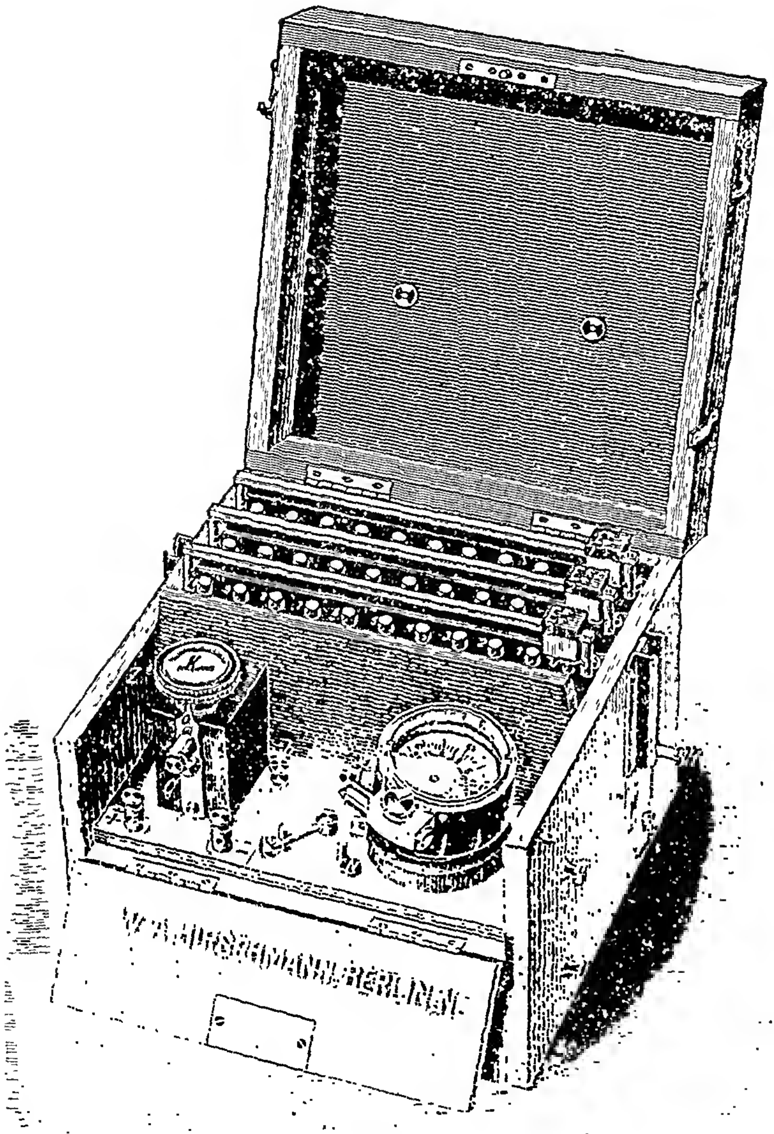


FIG. 40.

most firms for a very small price, and which works accurately; and

Rheostats

3. Generally also a small rheostat. Metal rheostats are not often used for this purpose, but either graphite rheostats (see Fig. 41), which, by the way, often work unevenly, or, what is better adapted for this use, Eulenburg's fluid rheostat (see Fig. 40, at the left, *Z*). The

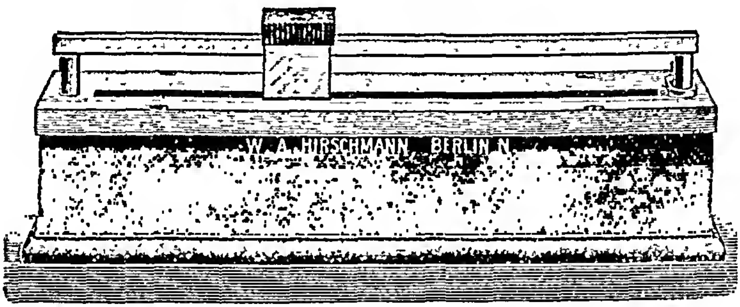


FIG. 41.—Graphite Rheostat.

latter consists of a small cylindrical box filled with water in which larger or smaller resistances are included by means of a screw-shaped arrangement.

The cells are included either by means of a cell-collector like that in the stationary apparatus (see page 9), or by means of a sliding arrangement which moves over the contacts on the plate and permits one cell after another and one row of cells after another to be used. (In the older apparatus, instead of this slide, there were arrangements for plugging. A progress from contact to contact was made possible in a complicated way by the insertion of a three-forked conducting-wire into metal sockets.) One must be sure to remember after use to separate the acid solution from the metal

rods, by lowering the trough which contains the fluid. For, as has been said above, the polarization in these plunge-batteries is considerable, and, therefore, they wear out very quickly. In many portable batteries an obstruction at the side of the box, which prevents it from being closed, acts as a reminder to lower the trough. In general, it is necessary to renew the solution in all these apparatus after several days' use, and from time to time to renew also the zinc rods. In setting up the apparatus one must be careful before using it that the needle of the galvanometer swings freely and points exactly to zero when the apparatus is at rest. In horizontal galvanometers of course it points nearly to the north when it swings freely. This must be regulated each time before beginning an electrical treatment by turning the apparatus or the galvanometer.

Modifications

The modifications of these kinds of apparatus are very numerous. Instead of plunge-batteries, with chromic-acid cells, others are made with Leclanché cells. But they are less fitted for transportation because of the weight which these relatively large cells add to the apparatus. Dry cells are rather to be recommended for galvanic apparatus because of their greater durability; but since the entire dry cell must be replaced by a new one when it is worn out, and the repairs are very considerable, the cost of maintaining the battery is somewhat higher.

On a pinch one can do without a rheostat in portable apparatus for practical purposes. To be sure, in that case, one must be willing to accept certain inconveniences

(*e.g.*, in galvanization of the head), and certain inaccuracies (*e.g.*, in determining the minimal contraction). But taking into consideration the small size, the low price, and the utility of the graphite and fluid rheostat it is preferable not to dispense with the advantages of this auxiliary apparatus. No one who would practise electrotherapy or diagnosis seriously dare acquire an apparatus without an absolute galvanometer in these days when they are made at all prices. One is utterly in the dark unless he knows each time the strength of current present; this will be sufficiently clear to the reader of this guide from what has been said in former chapters. Galvanization without a galvanometer is bungling.

The price of a portable galvanic apparatus furnished with a rheostat (fluid rheostat) and with a small absolute galvanometer varies between $60 and $300. Rheostats and small galvanometers can be bought at moderate prices.

After what has been said, it is probably unnecessary to add that the widely sold miniature apparatus for self-galvanization, which (applied, *e.g.*, in ladies' hats) are supposed to produce a continual, imperceptible "auto-galvanization" of the head and the like, are wholly useless if not injurious because of the lack of auxiliary apparatus, the inconstancy of the cells, and, above all, because of the lack of control of all important factors. At best their effect is suggestive.

Most firms manufacture a portable apparatus which contains the galvanic and the faradic apparatus in one case. The unavoidable increase in weight makes it less

easily carried, and the induction-apparatus can be less accurately regulated, as a rule, because of its necessarily small size.

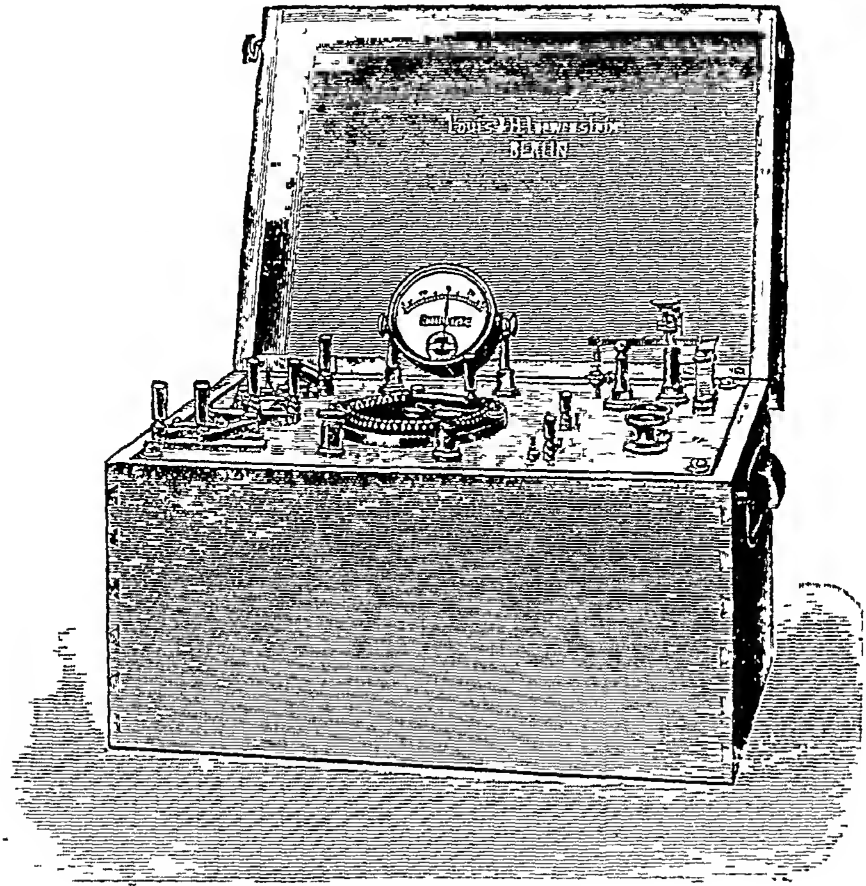


FIG. 42.—Galvano-Faradic Apparatus.

For him who wishes to have both currents without buying a large stationary apparatus, it is advisable to choose two portable apparatus—one constant and one faradic. It is not so necessary for a physician practising

in a large town to buy portable apparatus, because the larger firms rent them by the week or the month to patients at their homes. But in a small town or in the country a portable apparatus is more necessary to the physician than a stationary one. With two good portable apparatus one can get along very well, not only in his own house, but outside also.

Current-Changer

If it is desired to utilize the convenient current-changer (see pages 28 and 30) for two portable apparatus, which makes it possible, as in the large stationary ap-

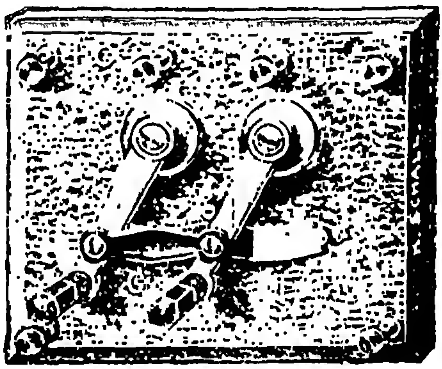


FIG. 43.

paratus, to get either the faradic or the galvanic current or both from one binding-post, this can be done very simply. On the table on which the two portable apparatus stand, and between them have fastened a small block of wood, with the de Watteville (Fig. 43) contrivance for changing the current (which may be bought separately in the electromedical factories); two connecting wires drawn across the table, which one can easily arrange himself, make the changing possible just as in a

stationary apparatus. Before transportation the contact arrangements are unscrewed.

In this way at a low cost one can procure almost all the advantages which a stationary apparatus offers.

Electrodes

As to the stock of electrodes, it will be well to have on hand covered, pliable plates of various sizes (200, 100, 50, 30, 20, 10, 5, 3 sq. cm.), and besides these several electrode handles, among them one with an interrupter (see page 40) which, tho not indispensable, is still very convenient for purposes of investigation. A brush or pencil-shaped electrode (see page 181) and a roll for massaging (see page 187) are likewise to be recommended. A neck electrode also is a convenience (see page 89). For local treatment with increasing faradic currents an uncovered button-shaped metal electrode is selected; Erb's electrode for determining sensibility is shown on page 148. The plate electrodes, covered with flannel or leather, which were formerly used, are to be discarded because they do not take up nor hold sufficient moisture. The best covers are those made of linen over a moss cushion. Care should be taken to hold these electrodes in water for some time, especially if they are new, in order that they may become thoroughly soaked. It is not sufficient to dip them in once; they must be soaked well if they are not to offer too great resistance to the current.

Special Electrodes

Special electrodes have recently been made for the stabile use of strong galvanic currents (see page 177, footnote) with which the ulcerating effect is done away with or considerably reduced. That of Bergonié is the original one. I myself occasionally use Luraschi's

(Milan) electrodes, which consist of rubber plates padded with clay and covered with parchment; they are flexible, and are kept continually in a 3.5 per cent. boric-acid solution. Both forms of electrodes make the use of high-current strengths possible by reason of their flexibility. Frankenhäuser's electrodes are so constructed that the electrolysis caused by the current takes place in the electrode and not in the patient's skin. Thus all ulcerating effects are avoided. Large and easily regulated rheostats are necessary when strong galvanic currents are used.

Results with Induction Apparatus

That a practitioner who possesses only one portable induction-apparatus, as is often the case, may achieve therapeutic results with it and get diagnostic indications, appears possible from what has been said in previous chapters. For most groups of diseases and single diseases methods are indicated which demand the faradic current, and which at a pinch may take the place of galvanic treatment. And as far as diagnosis and prognosis are concerned, the loss of faradic muscle and nerve excitability points to serious changes, whereas in one-sided peripheral affections, for instance, a retention of the normal excitability fully equal to that of the healthy side in all probability points to a slight prognostically favorable disease (granted that the necessary period of latency has passed since the beginning of the disease). This much is certain, that even with few appliances one who understands the methods will be able to accomplish much more than many who possess a complete collection of instruments.

CHAPTER X

III. Franklinization

By "franklinization" we mean the diagnostic and therapeutic application of Franklinic, quiescent, static, or tension electricity This is the form of electricity which originates from the friction of certain bodies and which is disposed to spread out on the surface of the so-called conductors, and to remain there, "quiescent," as it were, and in tension. It spreads out, especially at the end of these bodies, and the tension there is, therefore, greater than in the middle. It is greatest at the points. When it has passed a certain limit, the tense electricity leaves the body in the form of a spark, which forces its way through non-conductors, *e.g.*, the air, and struggles toward another point—that is, a discharging-conductor. Static Electricity

We distinguish two kinds (qualities) of this electricity; positive (glass) electricity, and negative (resin) electricity. Non-electric bodies are those in which both forms of electricity are actually present, in close connection, mixed, as it were, in equal quantities ("combined").

Through contact with electrical bodies the so-called non-electrical bodies may become electrical (electrical communication); they then receive that kind of electricity, which the body in contact has (positive or negative), and conduct it over their surface. Electrical Bodies

But electrical bodies also exercise an influence, at a distance, on the non-electrical. This is called induction. There occurs in the non-electrical bodies from the mere juxtaposition (without contact) of the electrical bodies a division of the kinds of electricity (electrical influence) present in them in such a manner that one kind of electricity collects at one end of the non-electrical body, the other at the other end (polarization of the body). *E.g.*, if the first electrical body is positive, then negative electricity collects at the end of the non-electrical body turned toward it, and positive electricity at the farther end, and *vice versa.* The latter (*i.e.*, the electricity of the farther end) may be discharged by contact with a conductor, such as the human body, *e.g.*, the finger, or some other conducting-substance connected with the ground. If that occurs, then the remaining (the negative) electricity spreads over the entire body.*

Condensers

But this second body reacting now "binds" a part of the electricity of the first, which can then take up new electricity, and so on. This is the principle of condensers. They serve to multiply (potentialize) the small quantities of electricity present. The Leyden jar or the Franklinic plate (an isolated glass plate, on either side of which there is a metal [tinfoil] coating) are condensers of this kind.

The influence-machines used by physicians are based

* If we wish to preserve the electricity present in an electrical body—that is, prevent it from giving off its electricity to the conducting-ground, we "insulate" it—that is, we separate it from its surroundings by a non-conductor, *e.g.*, glass, resin, or hard rubber. Air is also an insulator.

on this principle. A machine of this kind, widely used in Berlin, modified by Eulenburg according to Holtz's apparatus and made by Hirschmann, is represented in Fig. 44. Others prefer the Wimshurst machines, which are made by various firms.* The influence-machine en- Influence-Machines

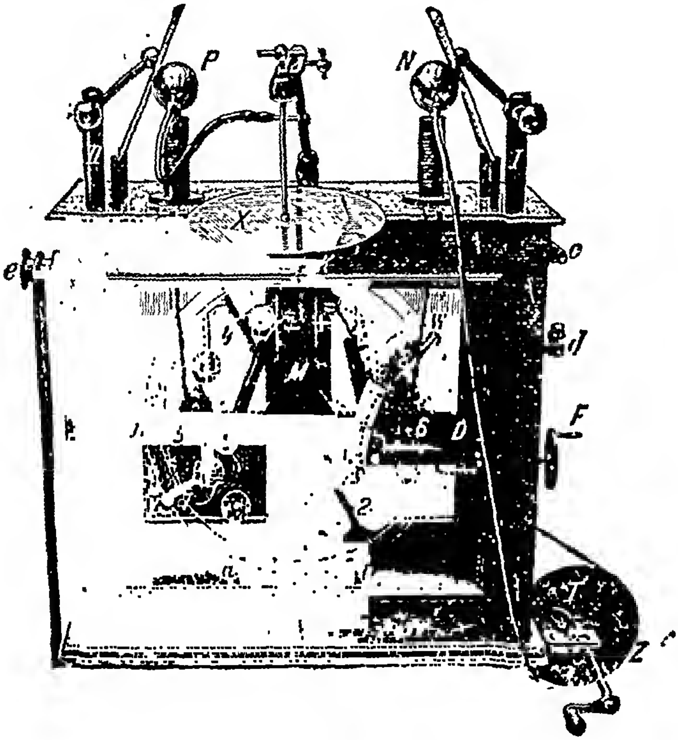


FIG. 44.

closed in a glass case (as a protection against dust and dampness) contains two glass plates standing parallel on edge, of which the one in the rear is stationary, the other in front rotatable by means of the wheel at *Z*.†

* Larger and more elaborate machines are in use in the United States; see Fig. 45.—Ed.

† The wheel is rotated by hand or by means of an attached motor.

Most of the other parts, important in using the machine, are fastened to a stationary bar of hard rubber, which crosses the case transversely (transverse bar *D.D.*). At *1* and *3* there are placed, diagonally opposite each other, two little wire brushes. Two similar ones are located at *2* and *4* on a diameter perpendicular to these, on an isolated metal rod (discharger) not numbered. On the rotating-plate there are placed in a circle at equal distances six small projecting metal knobs on little tinfoil plates. Now, if the rotating-plate is set in motion, the brushes strike the metal knobs, and by this friction produce small quantities of electricity. But the brushes, *1* and *3*, are both connected with the rear stationary plate by means of a conducting metal bow, *7* and *8* in the figure. Now, as soon as any trace of electricity is produced at *1*, say, by friction of the brush, it is taken up by the metal bow and conducted to the metal disk-plate *V*, on the stationary glass plate. Thence it spreads out (by means of a tinfoil plate) over a paper coating a little more than a quarter of a circle in size on the left side of the rear plate. Through further rotation of the plate the brush (*1*) is gradually brought into friction with all the metal knobs, and takes up more and more electricity from this friction, and gives it out, in the manner described, to the paper coating of the rear plate, where it is collected, so to speak. The paper coating becomes charged with a certain kind of electricity—that is, positive electricity. A very similar phenomenon is taking place on the diametrically opposite side of the glass plate, at brush *3*, where also, by means of a bow (*8*

in the figure) the paper coating of the rear plate is charged; there, however, with the opposite (negative) electricity.

Now there are suction-combs on the cross-bar (invisible behind *5* and *6* in the figure), one at the right, another at the left, which collect and lead off the two qualities of electricity from the plate at the rear—the one the

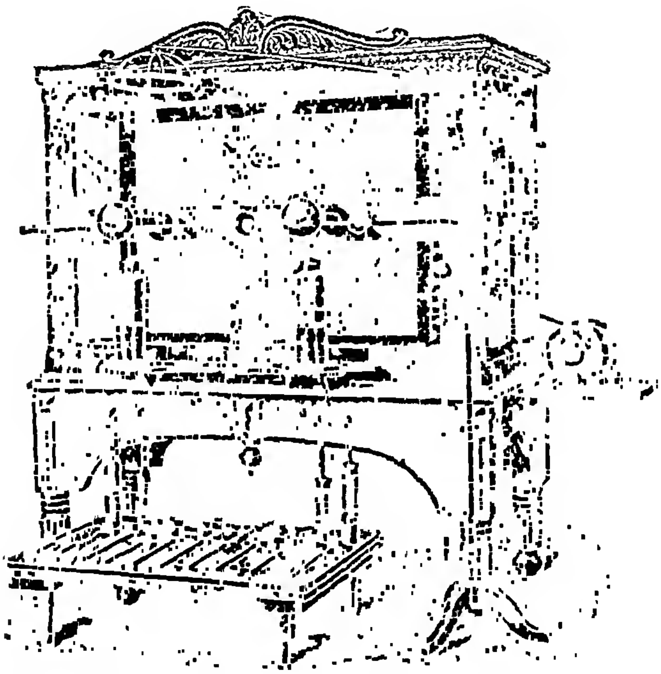


FIG. 45.—The Twentieth Century Static Machine, as Exhibited at the Pan-American Exposition.

positive, the other the negative. The more these combs lead off, the higher is the tension of the two opposite kinds of electricity, which by influence gather in the two

metal balls on the handles (which are visible above, about in the middle of the figure in the case, marked + and –). The metal (conducting) balls may be brought together or separated by means of the handle *F* at the right side of the case. If they touch, the two kinds of electricity neutralize each other on the way through them; if they are separated a little from each other, the neutralization occurs by means of a spark leaping between them. But if they are separated far enough they can not discharge, and then the two kinds of electricity, collected at the right and the left on the combs, are conducted by the metal connections placed at *5* and *6* through the cover of the case to the balls *P* and *N*, the + electricity to the one, the – electricity to the other.

By means of the conducting-cords attached at *P* and *N* and the connected electrodes, each of the two kinds of electricity can be conducted to the human body. For this purpose the conducting-balls + and – must be separated far enough (about 5 to 8 cm.) by means of the screw *F*, that no spark can leap between them. Then while one pole is connected with the body, the other is led to the ground or to an insulating-plate of hard rubber lying under the feet of the person experimented upon. Thus it is possible to conduct to the body a certain kind of electricity, positive or negative.

Determination of Poles

Since the machines, after long use, do not always become charged in the same direction, it is necessary to determine each time before using them which pole is + and which is –. This can be discovered best by approaching the conducting-balls to within 1.5 or 2 cm. of

each other and allowing the spark to jump; this shows a brightly shining streak at the + pole, a little shining point only at the − pole.*

But there is a second possible way of discharging the electricity furnished by the machine, which is used when we wish to get currents of higher tensions. Above, on the cover of the case, are two Franklinic plates (see above, page 235), which can be included in the current by placing on them two rod-shaped conductors at *I* and *II*. If the conducting-cords are now attached at *I* and *II* instead of at *P* and *N* and connected with the human body, the current goes through both metal coverings of the Franklinic plates. But, according to the laws of influence, the two coatings on each plate have two different kinds of electricity, and so with this arrangement the electricities of the inner coatings can neutralize each other, as can those of the outer coatings. The neutralization of the inner coating takes place within the case on the way through the conducting-balls, named + and −, that of the outer coatings through the human body. The farther the inside balls are apart and the more forcible the spark-discharge which takes place between them, the more forcible will be the discharge which follows in the body, which connects the outer coatings of the plates. Thus, when the plates are included, the condition is the reverse of that in the direct use of the apparatus. The force of Neutralization

* The insulated square metal rod not named in Fig. 44 (discharger), which likewise has two brushes and two suction-combs at both ends, serves to prevent "reversing of the poles" during a treatment. It is not necessary to go into the details of this.

the discharge in the body is proportional to the distance between the conducting-balls. On the scale *S* we can read the ball-distance (and the striking-distance) of the spark. This gives us a measure for the strength of the discharge in the body.

Therapeutic Use

For therapeutic purposes Franklinic electricity may be used either by direct conduction of the machine current from the contacts *P* and *N*, or in the manner described above, by conduction from the contacts *I* and *II*, after including the Franklinic plates.

The electrodes principally used are of three forms. The head-plate (see Fig. 44 at *X*), that of a point, or of a crown set with points—crown electrode—and that of a metal knob—knob-electrode.

The following methods of application have been recommended:

Point Radiation

1. Point radiation (discharging at *P* and *N*). The positive pole is connected with the electrode, armed with a point or a crown attachment, while the negative pole is connected with the ground or with an insulating foot-plate of hard rubber. The electrode should not be brought nearer the body than 2 cm. A distance of from 5 to 10 cm. is also sufficient. In this kind of application the conducting-balls must be separated so far that no discharge can take place between them (about 5 to 8 cm.). In this method of treatment brushes of light appear at the points and ozone is evolved. On the portion of the skin affected a pleasant breeze is felt. This treatment is recommended principally for paresthesias of all kinds and for neuralgias (*e.g.*, trigeminal neuralgia).

2. The head douche (also called the static douche). Here also the discharge is made from *P* and *N*, and what has just been said is to be observed in regard to the conducting-balls. By means of a short wire the negative pole is connected with the head-plate *X*, the positive with the ground or with the insulating plate. The plate *X* is movable by means of the screw *K*, so that it can be removed from or brought nearer the head, or also adapted especially to certain parts of the head. It must not be brought nearer than 5 cm. The nearer the plate the more intense is its action. By insulating the body by means of the foot-plate it may be increased. The duration of the treatment is about from five to fifteen minutes. Here, too, the feeling of a pleasant breeze occurs, as well as the standing on end of the hair. This method has been successfully applied in functional headache and migraine (especially the spasmodic form). **Head Douche.**

3. The static air-bath. With the same method of discharging and the same position of the conducting-balls as in 1 and 2 the body is placed on the insulating foot-plate, or on an insulating chair and connected with the positive pole, while the negative is conducted to the ground. Thus the patient remains for about ten minutes while the machine is set in action. Care should be taken that he does not touch a conducting-body, lest he get an unexpected electric shock. There is either no sensation or an indefinite one, similar to the one named above. **Static Air Bath**

In this application, as in all others, the patient may remain dressed.

The method is used in functional neuroses as a sedative to produce sleep, etc.

Spark-Current

4. The spark-current is applied in two ways:

(*a*) With the same arrangement as described in the above cases—that is, with discharging from *P* and *N* (with the conducting-balls separated). One of the two poles is then connected with the foot-plate, while the other, generally the positive, armed with the knob-electrode, is brought to the body. Even with the electrode at a great distance from the body (10 to 30 cm.) sparks leap through the clothing with a snap, and by moving the electrode at certain points (*e.g.*, muscle points) these can be insulated. This treatment, which has a strong stimulating and reddening effect on the skin, may be tried for anesthesias, neuralgias, diseases of the muscles and joints, as well as for functional disorders of all kinds. It has also been recommended for paralyses and atrophies.

(*b*) The second arrangement is a different one. The Franklinic plates are included, as described above (page 239); the discharge takes place from *I* and *II*, the conducting-balls are brought together, and thus the outer coating of one plate, *e.g.*, at *7*, is connected with a handle provided with a dry or a moist knob-electrode; that of the other plate is connected with the ground. The electrode is applied at the point of the body to be locally reached, *e.g.*, on a muscle point. Then the conducting-balls are separated slowly and gradually by turning *F*; discharges occur between them which correspond to equally strong discharges in the body. Even

with a ball-distance of 5 to 10 mm. contractions occur normally, which may be increased still more by increase of the ball-distance. Distances over 3 to 4 cm. should not ordinarily be used.

This method is occasionally employed in treating paralyses (or diseases of the joints). The electro-diagnostic attempts made with it have not yet attained a final conclusion (see also the Appendix: Discharging of condensers according to Zanietowski).

CHAPTER XI

IV. Teslaization

(The Application of High-tension Currents, according to Tesla and d'Arsonval.)

Principle of the High-Frequency Current

THE Croatian engineer, Nicola Tesla, has for many years been making experiments in the employment of currents for technical purposes, which differ from all currents hitherto known in their immense strength (Tesla-currents). About at the same time with him—and seemingly quite independently—d'Arsonval made a thorough study of the effect of such currents of extraordinarily high tension on animals and on the human body.

These "high-tension currents" are obtained by changing direct currents of relatively low tension (*e.g.*, the dynamo direct currents of the municipal lighting system) into alternating currents of exceedingly great rapidity. This is done in the following manner:

The current from the central system or from a powerful accumulating battery, before it is led to the body, passes through a large inductorium, strengthened by means of condensers (Franklinic plates), a so-called Ruhmkorff spark-inductor, which, by means of an enormous increase of the coils and by very frequent interruptions (produced by a mercury interrupter) is made strong

enough to produce, in certain cases, sparks of 25 to 50 cm. length (and more). If the Ruhmkorff is set going with the mercury interrupter in action, a current is received by conduction even from the secondary spiral, whose electromotor force (tension) is very great, considerably greater than the original and chiefly so as a result of the frequent change of direction in the induction-coil.

This high-tension alternating current is now conducted to two Leyden jars. As long as the induction-coil is active, there constantly leap between the dischargers of these jars sparks, whose strength and size grow with the power of the Ruhmkorff apparatus. These sparks, however, it has been proved, are not uniform streaks of light, but rather consist of innumerable, very rapid, invisible oscillations. Now, if the outer covering of the Leyden jars is connected with a solenoid (a short spiral of thick copper wire), there is produced in this latter a current with just as many interruptions as the leaping spark has oscillations; for every one of the hundred thousand oscillations per second which result means an interruption of the current circulating in the solenoid. Consequently, the current tension in the solenoid rises to from 100,000 to 1,000,000 volts.

This current may be conducted to the body from the solenoid itself or from a secondary spiral connected with it. It is so strong that, by mere radiation through the atmosphere, it causes an unconnected incandescent light to glow, tho held at a considerable distance (Tesla light).

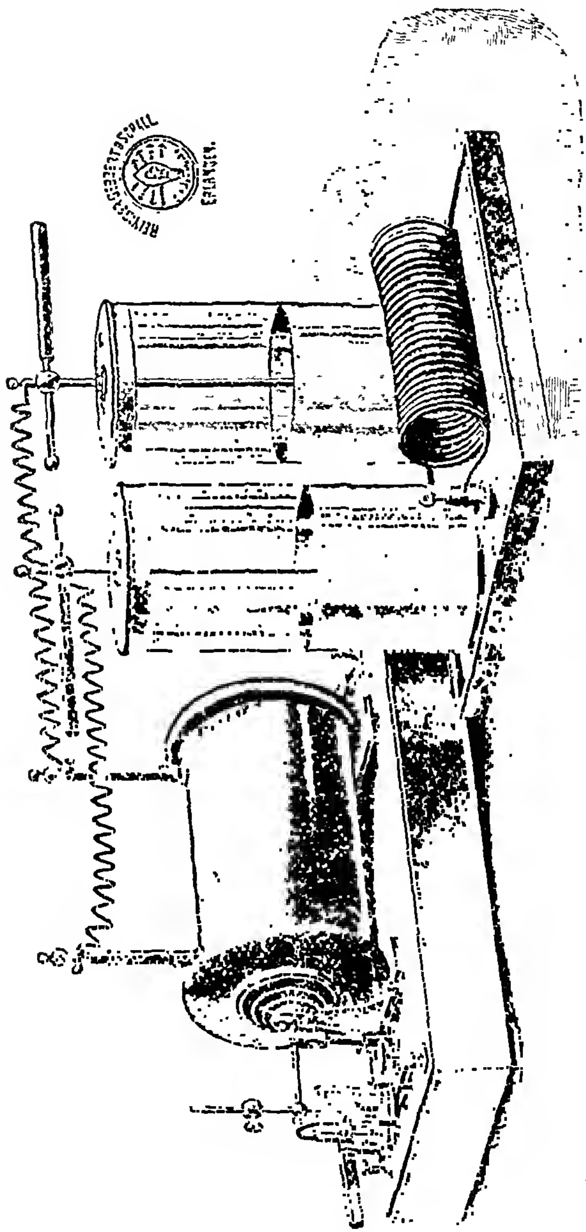


FIG. 46.—Apparatus for the Tesla Current—Ruhmkorff Inductor, Leyden Jars, and Solenoid.

In Figs. 46 and 47 there is shown one of the apparatus constructed for the application of "high-frequency currents," made by the firm of Reiniger, Gebbert & Schall Instruments

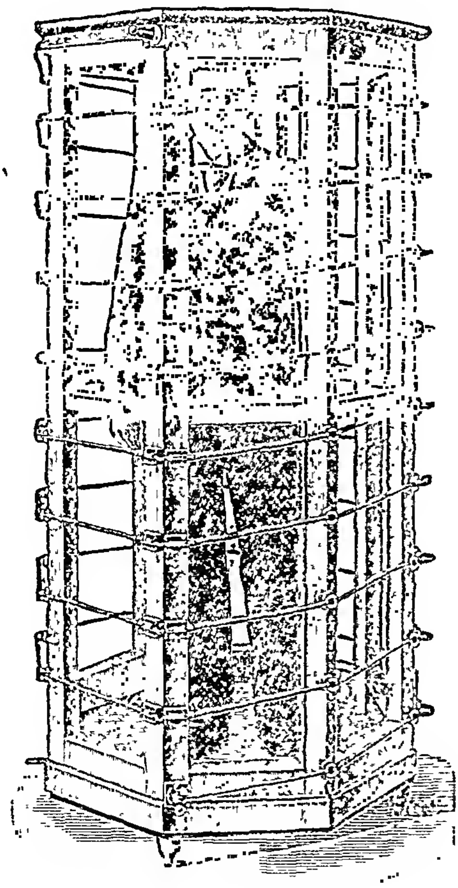


FIG. 47.—Large Solenoid for General Teslaization.

(without the wall-case and the current source). The diagram (Fig. 48) will explain the course of the current in such an apparatus.

From a current source (street-lighting system or accu-

mulating batteries) connections pass through a wall-case to the Ruhmkorff. The case contains the apparatus for regulating the current (resistances, current-reverser) and for measuring (amperemeter). Often it contains also

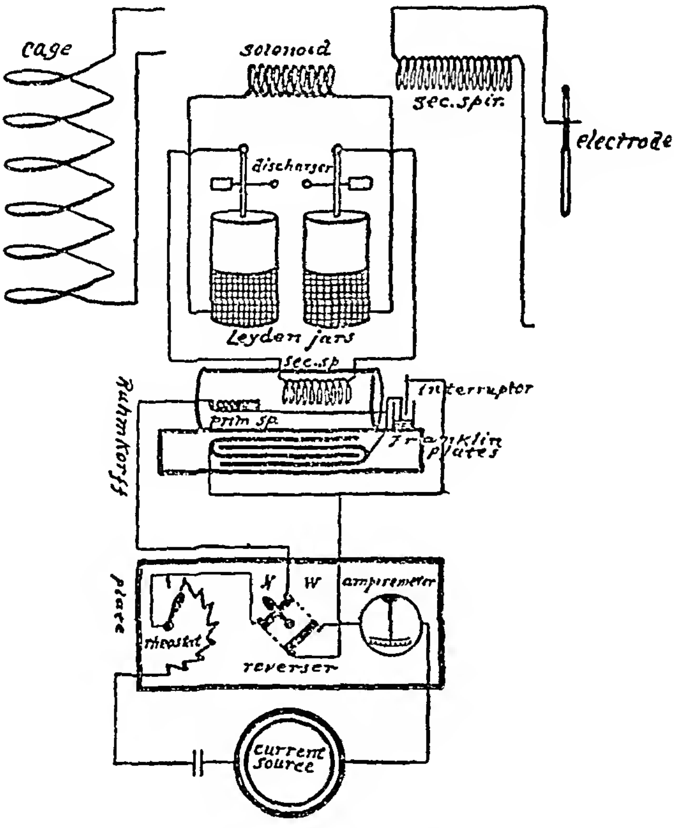


FIG. 48.—Diagram of Current Course in an Apparatus for High-Frequency Current.

the mercury interrupter for the inductor (in Figs. 46 and 48 it is at the right of the Ruhmkorff).

The Ruhmkorff, which in most apparatus produces sparks of at least 25 cm. length, is connected with the condensers—the Leyden jars—by means of two conduct-

ing-wires. At the upper end of the inner coating of the jars there are two metal rods with balls at the ends (dischargers), while the conductors from the outer coating lead to the two ends of a solenoid. When the apparatus is working, the equalization of electrical tension occurs in the form of a powerful spark (whose length can be regulated by moving the dischargers). As has been said above, the numerous invisible oscillations of this spark produce the desired frequent change of current direction.

From this enormously powerful current, which causes an incandescent light to glow by mere radiation, one should expect, *a priori*, an apparent and striking effect on the human body, especially on its motility and sensibility. This effect does not occur. As a rule, neither the local nor the general application of the Tesla-current causes either muscular contraction or sensation in the body. Physiology

Under longer influences (of the current), of course, a painful reddening of the skin, with swelling and occasional anesthesia, occurs, and when the part is touched lightly with the condensing electrode (to be mentioned later), a slight burning or prickly sensation, as well as slight contractions of the muscles, may be produced. But these phenomena are quantitatively out of all proportion to the immense current tension present.

Nevertheless, it is evident that the current passes the body, for if an incandescent bulb is placed in the hand of the person undergoing the test it begins to glow, but no sensation occurs.

Opinions differ as to how this fact is to be explained.

It is possible that the high-tension current produces opposite currents of equal tension in the body, by "self-induction" (see Extra Currents, page 27, footnote), and that these keep the current out of the interior of the body and merely allow it to glide over the surface, as it were; or it may be possible that the motor and sensory systems of the body are "focused" only for certain medium frequencies of current change, and respond as little to lesser and greater frequencies as the eye and the ear to lower or higher numbers of vibrations. Neither these two nor any other of the hypotheses offered have a sure foundation.

D'Arsonval's Experiments

The obvious inference that, lacking an external effect on the body, the internal effect of the Tesla current might be all the greater, seemed to be confirmed by d'Arsonval's experiments. He found, experimentally, increase of blood pressure in animals (reddening of the blood-vessels in the ear of a rabbit, etc.), as well as quickening of metabolic assimilation from the application of the high-frequency current, and he and other investigators, especially the French, believed that they had proved similar phenomena in human subjects. Further investigation (T. Cohn, A. Löwy, later Donner, Denobele, Carvalho, etc.) proved, however, that these observations were traceable to erroneous sources. The discoveries made by d'Arsonval as to the bactericidal effect of the Tesla current have also recently been contested energetically. Thus pretty nearly everything that has so far been reported as to the physiological effects of the Tesla current, as well as concerning the therapeutic in-

dieations for "teslaization," is of a more or less hypothetieal nature.

Suggestion probably plays an important part in sueeessful treatment (T. Cohn). Teslaization is espeeially recommended by Freneh investigators (Apostoli, Oudin, Doumer, ete.), and by others agreeing with them, for the treatment of: Therapeutic Teslaization

1. Diseases of metabolism: gout, diabetes, obesity, asthma, gall and kidney stones, rheumatism, anemia; also for malignant tumors.

2. Skin diseases: Eezema, aene, furuneulosis, herpes, psoriasis, liehen ruber, lupus, exudative erythema ete., (Aeeording to Eulenburg, really favorable results seem to have been attained in the treatment of these eases.)

3. Nervous symptoms: neuralgias and nervous diseases of the heart.

4. Diseases in the urogenital region in both sexes, as well as hemorrhoids.

5. Lately even for the treatment of pulmonary phthisis.

Reports of eures, espeeially in eases of the last sort, should be received with the greatest skeptieism. But it is very likely that the high-frequeney eurrent has a soporifie effeet.

In regard to injurious effeets of the current, nothing reliable ean be said. The statement made by some authors, that hysteria and neurasthenia are not influeneed at all or else unfavorably by teslaization, is not true aeeording to my experienee. Further observations must prove how mueh truth there is in the reports of

difficulty of breathing, dizziness, vomiting, and headache, as results of improper teslaization.

Methods The principal methods used are the following:

1. Local teslaization (direct conduction). Connections are made between both sides of the primary solenoid, or a secondary spiral of the same and the body of the patient (dressed); or with only one side of the solenoid, while the other is connected with the ground.

2. Condensation method (indirect conduction). A condenser is attached behind the solenoid or its secondary spiral before the current enters the body. Either a so-called condenser electrode is applied to the patient's body, or to a sofa (condenser bed), on which the patient lies, and whose under surface has a coating of metal. In both cases the body forms, as it were, the outer coating of a Leyden jar.

3. General teslaization (auto-conduction in a "cage"). A large upright solenoid (cage) is connected with the small solenoid. In it the patient may stand or sit without touching the conductor (see Fig. 47). The patient himself then forms a sort of closed conductor, encircled by the current (a secondary spiral, as it were). One need not be afraid of touching the coils of the solenoid or the conductors—as is clear from what has been said above, there is no sensation. (But an incandescent bulb on a short coil of wire, disconnected, introduced into the cage in place of the body, begins to glow.)

4. Resonance method (Oudin). A metal resonator, whose vibration numbers can be varied, is connected with a solenoid corresponding with it in capacity and

self-induction. The current, unipolar or bipolar, is conducted to the body by means of a glass electrode, which contains an oil-insulated metal wire.

The length of the application is from three to twenty minutes. The treatment should be repeated daily or every other day. Length of Application

The instruments are very expensive. However, it is considerably cheaper if one already has a Ruhmkorff, especially if the apparatus can be attached to the public lighting system.

APPENDIX

NEWER APPLICATIONS OF ELECTRICITY

As an appendix to the book something may be said of several varieties of the electrical current which, more or less recently, have been the object of scientific investigation, and which have also been recommended for diagnostic and therapeutic purposes. Altho they have no great significance for the practitioner, the most important facts in regard to them are given here for the sake of completeness.

The Magnetic-Electric Treatment

1. The magnetic-electrical current. As has been shown above (page 22 and following), a faradic current is produced if a current alternately appears and disappears in a primary circuit—that is, if a wire spiral is constantly moved toward and away from a primary circuit (*e.g.*, by rotation). Now, if we put a magnet in place of the primary circuit of a galvanic cell and swiftly rotate the wire spiral in front of it, the same phenomena appear in the spiral as with the faradic current—*i.e.*, with every rotation two opposite currents appear which may be conducted from the spiral to the body.

The so-called magnetic-electrical apparatus are constructed on this principle. In these two wire spirals on

a handle are revolved very rapidly by means of a multiplying cogwheel device in front of the poles of a horseshoe magnet.

The dynamos used for lighting and for technical purposes rest on the same principle. In these, however, there is generally an electromagnet instead of a simple (permanent) magnet, and hand power is replaced by mechanical power. In regard to their use for galvano-faradic apparatus, see page 220.

Magnetic-electrical apparatus have often been recommended as a substitute for the induction-apparatus, but are probably used only seldom on account of their inconvenience.

The Sinusoidal Current

2. The sinusoidal and undulatory current. The faradic current has, as is well known, this peculiarity: the two component, opposite current impulses are of unequal strength (see page 27, footnote). The opening current is much stronger than the closing current; the fluctuations of the electromotive force—graphically presented—form an irregular curve at every current impulse. The same in a lesser degree is the case with the magnetic-electrical current. But if we make an arrangement in which, by means of a so-called "transformer," the strong direct current from central stations or from accumulators is changed to a weaker alternating current, or if we have a weakened alternating current from a central station ready at hand, then we get a current curve whose graphic representation shows regular phases—pure circular sinus curves, which move alternately over and under the abscissa (for the alternating current im-

pulses of central systems do not show the irregularities mentioned above).

D'Arsonval and others after him have recommended these "sinusoidal" currents for medico-therapeutic use, especially for paralyses, atrophies, atonies, neuralgias, rheumatic affections, and in gynecological diseases for resorption of the products of inflammation, etc. He has also constructed an especial apparatus, which gives such a current independently of a central station.

The Undulating Current

A modification of this kind of current, the undulating current, has been mentioned by d'Arsonval for the same purposes. It is derived from the sinusoidal by connecting an automatic current-reverser, and is distinguished from it by the fact that the current curves have not the pure sinus form, but all have the same direction with reference to the abscissa: whereas those of the sinusoidal current now rise above and now sink below the abscissa, the wave movements of the undulating current all remain above this axis.

Sinus Form

Both currents differ in physiological effect from other induction-currents by reason of their greater mildness, lessened painfulness, which is a result of their greater evenness. The method of application is very easy and needs no special description.

The Jodko Current

3. The monodic Volta current (Jodko current). From a Ruhmkorff, as soon as it is connected with some current source (lighting system or accumulator battery), direct currents may be conducted to the body, one pole ending in a free point, while the other is connected with a copper wire immersed in a fluid. Stroking can be

done with the glass tubes containing the fluid. The free point may serve for local muscle stimulation, or the patient is exposed to its radiation in the manner of a static bath (see above, page 241).

The Condenser Discharges

4. The condenser discharges (after Zanietowski). It is well known that condenser discharges (see page 234) have a stimulating effect on nerves and muscles. Zanietowski, however, is the first to have made systematic investigations, in a series of noteworthy labors, as to the effects of such discharges, and he has found them eminently well fitted for therapeutic purposes (for painless electrization in pediatry, in neurasthenia, etc., for a massage-like shaking up of the fine tissues, etc.), and especially for finer diagnosis.

For this he uses minimal bipolar discharges (bipolar in order to prevent the electrotonic effects of one particular pole) from condensers of "optimal capacity" (that is, not too large, in order to avoid a too slow discharge and electrolysis; and not too small in order to prevent electrotonic influences). Thus he seeks to found a sort of electro-diagnosis with elementary stimulation, which may be of importance for the future of our science.

Value of Condenser Discharges

So far the chief results of his investigations are: (1) The compilation of tables of the (physiological) excitability for condenser discharges; (2) the discovery of pathological reactions to the form of current in question. Interesting diagnostic points have already been observed, and, moreover, the electro-diagnosis of all pathological changes in excitability is much more exact and easy by

means of the discharge because of its short duration and the absence of electrotonic current influences and those which change the resistance. In muscular dystrophy the absence of all condenser contractions, in spite of retained faradic and galvanic excitability, has been established; the myasthenic reaction of exhaustion appears with surprising slowness, the myotonic very plainly and painlessly. Attacks of tetany may often be predicted far in advance by increased condenser excitability; and in syringomyelia there are remarkable discoveries of electrical sensibility.

Zanietowski's apparatus, which consists of current source, condensers, a bipolar reverser, volt-regulator, and amperemeter, may also be used for galvanization, galvano-faradization, faradimetry, and for measurements of resistance.

Magnetic Treatment with Alternating Current

5. Treatment with alternating-current magnets (permea-electric treatment). This method of treatment, whose curative value the engineer, Eugene Conrad (Müller) recently discovered by accident, belongs, strictly speaking, not to electrotherapy, but is a special form of magneto-therapy, which has long been employed in other ways. With the latter the patient is exposed to the influence of a so-called permanent magnet (*i.e.*, a piece of steel permanently magnetized), while in the former we have to deal with an alternating-current electromagnet. By means of a coiled wire spiral an alternating current (or a direct current changed to an alternating one by a transformer) from a central source is sent through a hollow core made of numerous layers

of sheet iron. By this current of high intensity, but relatively low tension, and alternating frequency, 60 to 70 pole alternation, there is produced in the iron core a magnetism with changing polarity at the same rate. It then attracts strongly paramagnetic bodies (*e.g.*, iron filings), arranging them in the form of rays, and strongly repels diamagnetic bodies (*e.g.*, aluminum) without being changed by the interposed human body (the lines of magnetic force "permeant"). The part of the body to be treated is exposed to this magnetic field.

The instrument consists of the so-called radiator—that is, of a drum suspended movably with the cylindrical surfaces pointing up and down—consisting of slabs of serpentine. On the inside, in addition to the already mentioned electromagnet, there is a double—inner and outer—arrangement for cooling, to overcome the great heat which is produced. The current source is the central lighting system (in case of direct-current lighting with the addition of a transformer). A case contains the apparatus for conducting, measuring, and regulating the current, and the water-pipes. A large metal rheostat makes a gradation of the current possible.

If one side of the face is held toward the radiator, things seem to swim before the eyes; but this disappears when the eyes are closed, a phenomenon as yet unexplained. Other physiological effects are said to have been found in the increase of the oxyhemoglobin of the blood, sedative influence on the vasomotor system, etc.

This method of treatment is recommended therapeutically, especially for all kinds of neuralgias including chronic, as well as for neurasthenia, insomnia, vasomotor disturbances, angina pectoris, etc. (Rodari). Further investigation is necessary.

INDEX